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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. IX.

No. I.—JANUARY, 1912.

ORIGINAL ARTICLES.

I.—Note on a Nepheline-Syenite Boulder dredged from the Atlantic.

By Lady Rachel Workman McRobert.

THROUGH the kindness of Dr. Flett there has come into my hands an interesting boulder of nepheline-syenite belonging to Sir John Murray, dredged during the expedition of the *Michael Sars* (1) from the Atlantic Rise at a depth of 1,750 fathoms at a place about 150 miles south-west of the south-western corner of Ireland (Station 95 of the Reports of the *Michael Sars* Expedition). The slices examined were slides Nos. F 2092 to F 2095 from the Geological Survey Collection and two belonging to Dr. Peach. It is a boulder of remarkable freshness, and so entirely unlike any other specimen as yet recorded from the floor of the Atlantic that the question of its origin is of some interest. The fact that no other fragments of the same type were obtained in this dredging militates against the view that it is part of a mass in situ on the sea-bottom. Its companions from the same station, and in fact all the specimens collected by the *Michael Sars*, have been recognized by Dr. Peach and Dr. Flett as similar to rocks occurring commonly in Ireland, the North-West Highlands, and the Southern Uplands of Scotland, and not one among them is closely related to the nepheline-syenite. Rocks of Irish types have also been described by Professor Cole and Mr. Crook (2) as a result of earlier dredgings of the Atlantic floor, and again no specimen has been found remotely resembling the subject of this paper. It would appear likely, then, that this syenite boulder is of foreign origin and that it has been transported by floating ice moving southwards—an interpretation suggested by Dr. Peach for most, if not all, of the associated rock-fragments, which it is important to note were found embedded end-on in the ooze and, probably owing to bottom currents, not entirely covered up by silt. This he inferred from the distribution of the adherent organisms still to be found on the stones. Perhaps this syenite is derived from an unknown outcrop on the west of Ireland or Scotland, or on the sea-bottom off there. The shape of the boulder unfortunately gives us no assistance in the question of its origin. It is an angular block 6 by 2 by $4\frac{1}{2}$ inches, shows no ice moulding, and has evidently been lying in the ooze near the surface. It is hoped that the description given below may some day lead to the identification of its source, although at present this important point must be left in doubt.

The specimen is fairly coarse in texture, distinctly heterogeneous, and is composed of two parts separated by a perfectly distinct line—a dark-grey portion with good needles of hornblende and abundant sphene, traversed by lighter veins composed mainly of felspar, nepheline, and sodalite, and a light-grey part in which ferro-magnesian minerals are quite subordinate, while twinned crystals of orthoclase are conspicuous and with a marked tendency to orientation along the line of separation. Under the microscope the rock shows a fairly coarse hypidiomorphic structure. The minerals are all very fresh, and there is practically no sign of incipient decomposition along the cleavage or margins. In the pale variety of the rock the minerals are the same as in the darker portion, and only vary in an increased proportion of felspar and nepheline, and in their orientation. These circumstances and the fact that the small pale veins traversing the rest of the rock are of similar type seem to indicate that this is the last consolidated portion of the magma.

The minerals in their order of importance are—

Potash-felspar, mainly perthitic orthoclase in good twin crystals, best developed in the pale variety; also in close association with nepheline, often enclosing it poecilitically.

Soda-felspar, albite showing its characteristic fine lamellar twinning, present in very small amount and more idiomorphic than the orthoclase; it occurs also in very fine perthitic intergrowth with orthoclase. Microcline is absent.

Nepheline in perfectly clear large plates or intergrown with felspar, often crowded with fluid inclusions and small grains of augite.

Sodalite, crowded with innumerable liquid inclusions and minute crystals of the basic minerals, and presenting a cloudy appearance, with occasional aggregate polarization. It fills up spaces left by the felspar and nepheline, and is allotriomorphic. Rounded patches are also enclosed by large plates of felspar, so that it must have started crystallizing simultaneously with the felspar and continued subsequently. It is pale blue in hand-specimen.

Hornblende, greenish brown and very pleochroic; $a = X$ = yellow or pale brown, $b = Y$ = dark brown, $c = Z$ = dark brown; very intense in good idiomorphic crystals, with an extinction angle of 17° or 18°. The crystals are grouped together in close association with the iron-ores, sphene, and ægirine-augite. It is the chief ferro-magnesian constituent, and is moulded around the other above-named constituents. With ægirine-augite it occurs in parallel intergrowth, and often forms the outer shell of crystals in which the kernel is the pyroxene.

Ægirine-augite, a pale-green variety and occasionally lilac, slightly pleochroic from lemon yellow to pale green, with an extinction angle of about 25° or 30° and quite subordinate to hornblende.

Sphene, in excellent double-wedged lozenges frequently twinned, of a curious pale yellow grey, with a pleochroism marked by variation of intensity rather than of colour. The margins are often corroded. Its inclusions are of apatite, felspar, nepheline, and even sodalite in some instances, thus further confirming the long period of crystallization of the latter.

Magnetite, in irregular grains and hexagonal crystals, containing

inclusions of apatite, and generally surrounded by a green rim of pyroxene. In some instances it forms the nucleus of crystals of ægirine-augite, surrounded by hornblende. It is restricted to portions of the slide rich in these. Some of the iron-ore seems to be titaniferous, and in one instance shows alteration to leucoxene.

Apatite is abundantly scattered throughout all the minerals in small crystals, usually taking the form of elongated needles.

A consideration of these minerals and their association leads one to assign this specimen to the foyaite type; the percentage of potash-felspar is high and slightly exceeds that of the nepheline. The ferro-magnesian minerals are of minor importance, their chief constituent being an amphibole, so that this rock may be added to the comparatively restricted list of Amphibole Foyaites, and as yet none of these have been recorded from the Atlantic coasts.

In this basin some of the most noteworthy occurrences of nepheline-syenites are in the Sierra de Monchique (Portugal) (3), in the Langesundsfjord (Southern Norway) (4), at Julianchaab in Greenland (5), at Salem, Essex Co., Mass. (6), and Beemerville, N.Z., and in Assynt, Sutherland (7).

The specimen under consideration seems to have very little affinity with any of these. One essential difference from the rocks in Portugal, Norway, and Salem, Mass., is, that these are all pyroxene foyaites. The boulder further differs from them in the absence of biotite, and in the case of the last-named one, in the absence of zircon and eudialite. It shows none of the peculiar radial structure so marked in the pegmatite of Låven, Langesundsfjord, and of the harbour at Salem. The possibility of its migration from Greenland is minimized by the completely different character of the rocks from Julianchaab, described by Ussing, up to the present. He distinguishes three chief types—

(*a*) A sodalite-syenite, in which sodalite is embedded in tiny idiomorphic crystals in felspar, nepheline, eudialite, and ægirine alike.

(*b*) A foyaite type, coarse-grained and composed of eudialite, microcline, microperthite (in broad plates), nepheline, ægirine, arfvedsonite, and a little sodalite.

(*c*) A fine-grained variety with narrow felspar laths, acicular ægirine, and much iron.

The melanite-bearing rock from Loch Borolan is too well known to require description, and it is evident that the boulder in no way resembles it.

Conclusion.

The outstanding characteristics of the nepheline-syenite boulder here described are thus: its great freshness, the restricted number of its minerals and their normal habit, the prominence of hornblende, the complete absence of all rare minerals such as are so commonly found in nepheline-syenites, and the presence of a fair amount of iron-ore, although the rock is by no means very basic. It cannot at present be compared with any known syenite of the North Atlantic basin.

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(1) Hjort, J. "The *Michael Sars* North Atlantic Deep-sea Expedition, 1910": Geogr. Journ., xxxvii, 4, 5, 1911.

(2) Cole, G. A. J. & Crook, T. "On Rock-specimens dredged from the Floor of the Atlantic off the Coast of Ireland": Mem. Geol. Surv. Ireland.
(3) Weroeke, L. van. "Ueber den Nephelinsyenit der Serra de Monchique": N.T., 1880, ii.
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Sears, J. H. "On Occurrence of Augite and Nepheline Syenites, Essex Co.": Bull. Essex Inst., 1893, xxv.
(7) Horne, J. & Teall, J. J. H. "On Borolanite": Trans. Roy. Soc. Edinburgh, vol. xxxvii, pt. i, 1892.

II.—On a New Species of Mouse and other Rodent Remains from Crete.

By Dorothea M. A. Bate.

ON looking over a small collection of rodent remains from the Pleistocene cave-deposits of Crete, Mr. Oldfield Thomas drew my attention to one specimen which appeared to be of special interest. It consists of an imperfect right mandibular ramus still in the matrix, and which contains the base of the incisor in a fragmentary condition, and the first and second molars in a perfect state of preservation. The third molar is missing. This specimen was obtained from a cave-deposit on the south side of the little bay of Sphinari[1] on the west coast of Crete. The deposit is almost totally destroyed and is still partially submerged; a few fragmentary remains of an ungulate were also observed and appeared to be those of the Cretan deer *Anaglochis cretensis* of Simonelli, which occurs in so many of the cave-deposits of the island.

It is always unfortunate when a new form is represented by one or two fragments, as in this case, for the scanty material available makes it impossible to speak with certainty of its closest affinities. The molars under discussion are typically murine in pattern and must have been those of a mouse of very large proportions, one which, so far as I am aware, has no equal in size in the Mediterranean region. It is therefore proposed that it should be known as *Mus catreus*, it being understood that the generic name is here used in its older and wider sense. The fact of an innominate bone of large size and presumably belonging to this species having been obtained from another cave-breccia in the island lends additional weight to the belief that it is not the remains of an individual 'sport' that are being dealt with, but that these more probably represent another instance of a giant form occurring among the smaller mammalian fauna of an island.

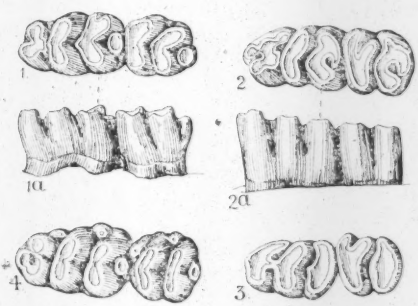
The two molars in the Cretan specimen are high-crowned and not very broad. They are not in an advanced stage of wear; the triturating surfaces of the parallel tubercles of both teeth have been worn to a common level, but the two anterior laminæ of the first tooth are barely connected to form the square cross of the typical Murine m.1.

[1] "Pleistocene Mammalia in Crete": Geol. Mag., n.s., Dec. V, Vol. II, p. 197, May, 1905.

Both molars have well-developed supplementary cusps. With regard to the height of the crowns Mr. Hinton pointed out to me that in this they approach *Rhagamys orthodon* of the Pleistocene cave-deposits of Sardinia and Corsica, and at first sight the resemblance seemed to be sufficiently close to warrant their inclusion in that genus. However, there is perhaps hardly sufficient data at present to justify this, for, although the Cretan molars are decidedly high-crowned, it will be seen from the measurements given below that they are not more so than obtains in *Cricetomys*. Further, while m. $\frac{1}{1}$ in *M. catreus* is twice the antero-posterior length of the corresponding tooth in *R. orthodon*, the height of its crown is only one-third more. The following measurements, in millimetres, will give some idea of the comparative sizes of the Cretan mouse, *Epimys*, *Rhagamys*, and *Cricetomys*.

	E. rattus.	*E. decumanus.*	*R. orthodon.*	*M. catreus.*	*Cricetomys.*
Ant.-post. length of $m.\frac{1 \text{ and } 2}{}$.	4·5 ...	5·5 ...	4·5 ...	8 ...	8·5
Ant.-post. length of $m.\frac{3}{}$ . .	— ...	— ...	2·5 ...	5 ...	5
Greatest width of crown . . .	2 ...	— ...	2 ...	3 ...	—

The width of crown in a worn specimen of *E. decumanus* is slightly more than 2 mm. In *Cricetomys* the complete series measures 11·5 mm. antero-posteriorly, while in *E. decumanus* and *E. rattus*



FIGS.
1, 1*a*. First and second right lower molars of *Mus catreus*, n.sp. 1, crown view; 1*a*, inner view. × 3.
2, 2*a*. *Rhagomys orthodon*, Hensel, sp. 2, crown view; 2*a*, inner view. × 5.
3. Ditto. Crown view of teeth in more advanced state of wear. × 5.
4. *Cricetomys*. Crown view. × 3.

this measurement is 7 mm. and barely 6 mm. respectively, and in a specimen of *R. orthodon* from Corsica 5·5 mm. The greatest height of the Cretan molars above the inner alveolar border is 3 mm. and is practically similar in *Cricetomys*, while in a Sardinian example of *R. orthodon* this is very slightly more than 2 mm.

From the above it is evident that the molars under discussion are those of a much larger animal than either *R. orthodon* or *E. decumanus*.

and that in fact it agrees in this respect with *Cricetomys*. In spite of the similarity in size the Cretan molars are at once distinguishable from those of *Cricetomys* by the presence in the latter of two extra tubercles on the outer border of both m. $\frac{1}{1}$ and m. $\frac{2}{2}$.

Although not very worn there is no sign in the Cretan specimen of the third anterior cusp in m. $\frac{1}{1}$ which seems to persist for a considerable time in the examples of *Rhagamys* from Sardinia and Corsica which I have examined. This extra anterior tubercle is given by Dr. Forsyth Major[1] as one of the characteristics of *R. orthodon*, in which it agrees with the group of mice including *Apodemus sylvaticus*, and differs from that containing *Epimys* and *Mus musculus*. The paired tubercles appear to be somewhat further apart in *M. catreus* than in *R. orthodon*.

A small piece of very hard breccia from another Cretan cave-deposit contains an imperfect left innominate bone believed to be that of the species to which belong the molars described above. The inner surface of the acetabular region is exposed, and, although only partially preserved, it is evident that it must have belonged to a Murine of considerably stouter proportions than *E. decumanus*. Further, the iliac crest springs from the ilium very close to its acetabular end, much more so than is the case in *E. decumanus*, and in this agreeing with *Cricetomys*, although the whole specimen is somewhat less robust than in the latter. *Cricetomys*, it will be remembered, is a recent genus distributed over the whole of inter-tropical Africa, but, so far as I am aware, has not been obtained in a fossil state.

Other rodent remains found in the Pleistocene cave-deposits of Crete include those of an *Acomys*, still found in the island, and also of *Epimys rattus*. This last is of more interest than might at first be supposed, not only as indicating coexistence with *Mus catreus*, but also because at the present day rats are found only in the towns and villages. In Cyprus a brown form of *E. rattus* is extremely common, both close to human habitations and in the country, and it is a significant fact that there is no weasel or stoat in that island. In Crete, on the other hand, a large weasel occurs,[2] consequently the finding of the fossil remains of a rat raises the question as to whether this rodent roamed over the island until its radius was checked and circumscribed by the comparatively late introduction of the weasel, by which it has been supplanted.

It may be of interest to note that one of the characteristics of the plentifully distributed Cretan field-mouse[3] of the present day is that in size it is inferior to other Mediterranean forms.

Remains of the *Myoxus* found by Spratt and identified by Falconer were not met with by me.

[1] "Rodents of W. Mediterranean": GEOL. MAG., N.S., Dec. V, Vol. II, p. 503, 1905.

[2] Proc. Zool. Soc., vol. ii, pp. 319–20, 1905.

[3] "*A. sylvaticus creticus*, Miller": Ann. Mag. Nat. Hist., ser. VIII, vol. vi, p. 460, November, 1910.

III.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from Decade V, Vol. VIII, p. 156, 1911.*)

(PLATE I.)

Discoflustrellaria Trimensis, sp. nov. (Pl. I, Figs. 1–3.)

Zoarium small, highly conical, slightly compressed in one direction, very fragile.

Zoœcia rather bluntly hexagonal, subradially arranged in straight rows which from time to time diverge to admit a new row, length ·35–·4 mm., width about the same; the area varies from distinctly elliptical to practically circular; maximum length ·33 mm., breadth ·3 mm.

Oœcia apparently not uncommon, though delicate and rarely well preserved; they are strongly inflated, but nearly rectangular in plan, with the free edge straight (when perfect); they roof in the upper end of the zoœcia, which is of abnormal length, and remain conspicuous by their length when the oœcia have been destroyed; they tend to encroach slightly on the area of the succeeding zoœcium.

Avicularia of the hour-glass type, closely resembling those of *Membranipora anguiformis* (*ante*, April, 1910), but with the upper part of the hour-glass larger than the lower and with indications of a slender bar crossing the lower end of the neck of the hour-glass similar to those shown by *Membranipora sagittaria* (*ante*, April, 1910). They seem to be confined to the beginning of new rows of zoœcia.

The species occurs very rarely at Trimingham, and but for the single specimen shown in Fig. 1, which is perfectly discoidal, though as a cone it has lost its apex, I should not have ventured to publish the opinion I had formed from fragments that it was a *Discoflustrellaria*. The species is easily distinguishable by its avicularia (the 'cellules avortées' of the generic diagnosis).

Lateroflustrellaria robusta, sp. nov. (Pl. I, Figs. 4–10.)

Zoarium strong, typically conical, but varying in height from 3 to 5 mm.; the high specimens are generally rather elliptical, the low ones are generally circular.

Zoœcia symmetrically hexagonal; the initial (and central) zoœcium is quite abnormal, being larger than the others and shaped like an elliptical funnel, at the bottom of which is a long and narrow triangular aperture with a stout and blunt projection from each side; over the base of the triangle and hiding the greater part of it there hangs a short, broad, rounded projection at a level a little below the rim of the funnel; round the initial zoœcium there is a ring of zoœcia of approximately normal size and shape, but retaining modifications of the stout internal projection of the initial zoœcium, which often simulate a front wall of ordinary Escharine type; outside this ring the zoœcia (except for the first one or two of a row, which may be subtriangular) are all alike, appearing on the surface as a regular network of large, very slightly elliptical apertures with thin boundary walls, divided from one another by fine sutures, and curving downwards

so that each passes under the preceding one; indications of paired round pores in the end wall some way below the surface-level are seen from time to time; length about ·52 mm., breadth about ·48 mm., diameter of aperture about ·4 mm.

Œcia short low and wide hoods occurring only near the outer margin of mature zoaria, and so inconspicuous that they can only be distinguished with certainty from slightly projecting zoœcial walls by looking horizontally along the zoarial surface.

Basal lamina smooth, divided by more or less radiating sutures into lines corresponding with the real (but not the apparent) distribution of the zoœcia on the upper surface; the outlines of the individual zoœcia are almost always quite obliterated; the method of growth leaves a very characteristic impress at the edge of the zoarium, by which the nature of quite small fragments may often be recognized; pores occur irregularly in the lamina and are probably connected with the internal pores above mentioned.

Not uncommon at Trimingham, and owing to its robustness often well preserved. By the initial stages and the presence of oœcia it is easily distinguished from the only other Cretaceous *Lateroflustrellaria*.

EXPLANATION OF PLATE I.

(Figs. 1–4 from photographs by the author, Figs. 5–10 from drawings by Miss G. M. Woodward.)

Fig. 1. *Discoflustrellaria Trimensis*. A specimen, natural size.
,, 2. Ditto. A fragment of another specimen. × 12.
,, 3. Ditto. Ditto.
,, 4. *Lateroflustrellaria robusta*. A specimen, natural size.
,, 5. Ditto. The greater part of a very flat specimen, showing the parallel rows of zoœcia continuous past the central (initial) zoœcium. × 8.
,, 6. Ditto. The initial zoœcium and surrounding zoœcium from the specimen shown in Fig. 5. × 12.
,, 7. Ditto. Ditto, from another specimen. × 12.
,, 8. Ditto. Ditto.
,, 9. Ditto. Underside of another specimen. × 6.
,, 10. Ditto. Underside of and cross-section through another specimen, in which the individual zoœcia are still traceable. × 6.

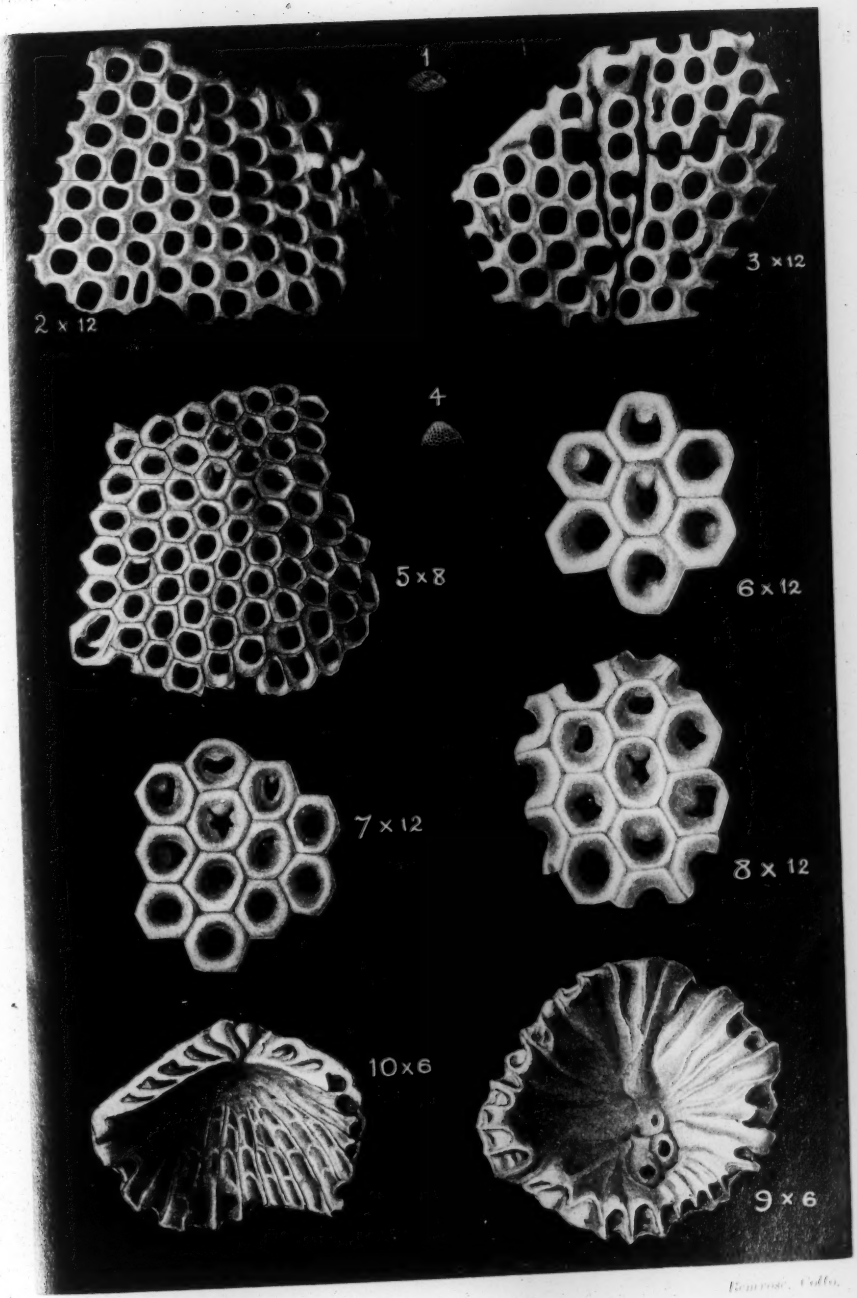
IV.—On the Evolution of the Apical System in the Holectypoida.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

(PLATE II.)

A. Introduction.

In two previous papers in this Magazine (Hawkins, 1910 and 1911) I have dealt with some features in the comparative anatomy of the ambulacral and interambulacral areas of the Holectypoida. The only other structure of the test for a comparative study of which sufficient material is available is the apical system. The present paper deals with this structure. I intend to summarize the results



Chalk Polyzoa.

of my researches in a scheme for the classification and evolution of the group in a paper already partly prepared.

B. The points to be examined.

The apical cycles of plates are of fundamental importance in an Echinoid. Not only are they directly associated with the reproductive system, the water-vascular system, and some of the more delicate of the sensory organs of the animal, but it is from their outer margins that all the new coronal plates arise. The differences of structure which are shown in the apical system in various groups must therefore be indications of essential differences in the structure and development of both the skeletal and softer tissues of the body. From the foregoing sentences it will be realized that I differ considerably from the opinions expressed by Duncan (1889), and tend to regard the apical system as a phylogenetic index of the first importance. Nevertheless, I do not absolutely follow Pomel (1883) in treating the structure as the *chief* or only guide in classification.

Many careful studies of the apical system of Echinoids have been made, and the contrasts in its structure figure largely in the diagnoses of the larger and smaller groups. Many of the investigations were undertaken as a result of the brilliant, though apparently mistaken, attempt of P. H. Carpenter to homologize the apical cycles of Echinoids with the calycal cycles of Crinoids. The *Études* of Lovén (1875) contain perhaps the most important contributions to a comparative study of the structure from this standpoint that have been comprised in a single work.

Within the limits of one group of Echinoids there are usually not sufficiently marked differences of structure to render worth while the publication of detailed descriptions of the apical system alone in allied genera and species. In the case of the Holectypoida, however, the changes in detail are so many and so striking that a comparison, between genera at least, seems to lead to important results. No more convincing proof of the intermediate position occupied by the group between the various Echinoid orders can be supplied than that which a study of the apical system affords. And conversely, it is because the Holectypoida are an annectant group that the various forms show such a plasticity of structural development.

Almost the only reliable distinction between the early Holectypoida and the primitive Diademoids lies in the position of the periproct. However excentric the anus may be, it is always enclosed within the boundaries of the apical system in the Regular Echinoids. In *Pygaster*, for the first time in Echinoid history (if we except the aberrant and somewhat problematical 'Acyclic' Silurian forms), the periproct passes backwards to lie outside the cycles of the genital and ocular plates. Thanks largely to the work of A. Agassiz and S. Lovén, we now know that many, probably all, of the Irregulares, even of the Spatangoids, pass through a 'Regular' (though often *functionally* aproctous) stage in the course of their ontogeny. This means that the primitive apical system must, in every individual, be ruptured for the retrogression of the anus. Another result is that, even if the system regains its original quinqueradial symmetry, it

will have to become a compact group of plates instead of a hollow ring enclosing a membrane-covered space.

There are thus two features in which the evolution of the apical system of the primitive Irregular Echinoids may be profitably traced. The first is *the recovery of the complete cycle* of plates, and the second the method of *the infilling of the centre* of the system.

Discussions and brief descriptions of the structure of the apical system in typical genera will now be given, and subsequently the stages in its evolution will be summarized.

C. The Apical System of *Pygaster*.

As far as the characters of this structure are concerned, the species of *Pygaster* fall into two well-marked groups. These groups correspond to the divisions named by Pomel (1883) '*Plesiechinus*'[1] and *Pygaster* [*sens. str.*]. The differences in the apex are due to the different shape of the periproct in the two divisions. In the '*Plesiechinus*' section the periproct has its greatest width in the adapical portion, while in *Pygaster*, *sens. str.*, the upper part is narrow, and the greatest width of the periproct is about midway between the apex and the margin of the test. '*Plesiechinus*' comes first both in stratigraphical occurrence and in phylogenetic order. *P. macrostoma* (Wright) is the only species of the group in which the apical system seems to be known. This species was suspected by Wright himself (1860) to be only a variety of *Pygaster* '(*Plesiechinus*)' *semisulcatus*, and it may at least be taken that the apical structures were similar in both forms. '*Plesiechinus*' may be said to contain those species in which the periproct has only just broken through the apical system, or even is in the act of breaking through. In *Pygaster*, *sens. str.*, it has, for the most part, receded from the apex, and the sides of the interambulacrum are closing in to heal the gash caused by its passage. *Pileus* marks the complete accomplishment of this process.

1. '*Plesiechinus*' (Pl. II, Fig. 1). In the Supplement to his Monograph, Wright (1860) figures the apical system of a small individual of *P.* '(*Plesiechinus*)' *macrostoma* (pl. xli, fig. 5*b*, by error termed *megastoma* in the legend). The drawing (copied in Pl. II, Fig. 1, of this paper) shows the apical plates to be arranged around the upper edge of the very large periproct and to form a smooth, apparently complete, margin to the aperture. Only four *genitals* are present, arranged in an almost linear manner transversely to the diameter of the test. Of the five *oculars*, the three anterior plates are normally situated in the angles of the genitals, while the two posterior plates rest against the posterior margins of the two postero-lateral genitals. In view of the fact that the posterior margin of the system is regular, with no considerable re-entrant angles, and that the posterior oculars do not reach to the periproct margin, it seems

[1] This name is systematically indefensible, being synonymous with Agassiz's *Pygaster*, whose type is *P. semisulcatus*. I use it in inverted commas here to avoid systematic discussions in a morphological paper.

certain that the fifth (posterior) genital did not exist. At most it may have been represented by one or more small plates situated on the anal membrane, and not necessarily distinguishable from the other anal plates. We find, then, that the first effect of the shifting of the periproct was the actual destruction of the odd genital plate, and the spreading out of the rest of the system into a transverse line of plates. The *madreporic genital* is larger than its fellows, but not very much so, and, as the whole system is not a cycle, it cannot be said to intrude at all into the centre of the apical system.

In '*Plesiechinus*', then, the system is absolutely ruptured, with no attempt at repair, while there is equally no trace of any infilling of the central part of the 'disc'.

2 *Pygaster, sens. str.* The apical system is well known in *P. umbrella*, *P. dilatatus*, and *P. macrocyphus*. Cotteau (1874) figures the system in all three species, and I have a specimen of *P. umbrella* in my collection in which most of the plates are well preserved. In this group, owing to the closing in of the upper part of the interambulacrum upon the adapical portion of the periproct, it is possible for the apical system to begin to reassume its cyclic character. In the work just referred to Cotteau seems to assert the presence of five *perforated* genitals in the genus, but this is certainly a mistake. (His figures give no support to his assertion.) Pomel (1883) is nearer the truth in his statement that the place of the fifth genital is taken by several small plates. I have not seen any specimens or figures which show any such plates preserved, but, judging from the facets on the posterior margins of the plates in my specimen, it seems certain that *at least one* plate occupied the position of the posterior genital. This will have been a roughly pentagonal plate (marked A in Pl. II, Fig. 2), in contact with the madreporic genital and the right posterior ocular, situated somewhat to the right of the antero-posterior axis of the system. To complete the symmetrical outline of the system it is necessary to postulate the presence of one or more smaller plates besides this one. Their probable positions are indicated in Pl. II, Fig. 2, by dotted lines.

The most striking feature of the apical system in this group is the enormous size of the *madreporic genital*. Not merely is it wider and more convex superficially than the other genital plates, but it extends inwards and posteriorly through the system, entirely separating the other genitals from one another, and monopolizing all the central space. In fact, the madreporite occupies just the position which, in a Regular Echinoid, would contain the anus and its membrane. The genital pores are relatively small, and each is encircled by a prominent raised rim. The *ocular plates* are small, and are rendered the less conspicuous by their depression below the general surface-level of the surrounding plates. They slope away from the centre, so that the ocular pore opens in a considerable hollow. After the pore is passed, however, the surface of the plate rises sharply to meet the proximal coronal plates.

Judging by Cotteau's figures of the apical system of *P. truncatus*, it would seem that in that species (the type of Pomel's third 'genus'

Macropygus) the structure is similar to that obtaining in *P. umbrella*. Indeed, it is natural that this should be the case, for the shape of the periproct is similar in both forms.

Pygaster, sens. str., and *Macropygus* show an attempt to reconstruct the cycle of the genitals by the development of one or more plates in the posterior part of the system, while the centre of the system is filled up by the intrusion and expansion of the madreporite.

D. The Apical System of *Anorthopygus*. (Pl. II, Figs. 3, 4.)

Although contrary to the true stratigraphic sequence, it seems best to discuss this genus directly after *Pygaster*, as its apical system has more pronounced affinities with the *Pygaster* type than with that of its associates in the Lower Cretaceous. In all but the tuberculation and the position of the periproct it is a *Pygaster*, and was classed as such long after its specific recognition.

Cotteau (1859 and 1861) gives good figures of the apical system in both species of the genus. There are several siliceous moulds of *A. orbicularis*, from the Haldon Hill drift, in the British Museum, and they serve to verify the drawings taken from Continental specimens.

The system is a complete cycle, and, as far as its outline is concerned, is almost radially symmetrical. In spite of this appearance it is in reality of quite unsymmetrical structure. There are only four *genital plates*, the posterior one being absent. Three of the remaining plates are of uniform size, but the madreporic plate is so extended as to render the system actually ethmolysian. In *A. orbicularis* (Pl. II, Fig. 4) this large development of the right anterior genital is not carried out at the expense of the size of its fellows, as it is in *Pygaster*, for it is very little wider than the other three genitals. The posterior part of the plate has the outline of a perfectly normal fifth genital, and appears sharply marked off from the central (madreporiform) part of the plate. There is, however, no trace of a suture. The second species, *A. michelini* (Pl. II, Fig. 3), has, according to Cotteau, a much more *Pygaster*-like apical system. In it the madreporite is expanded transversely as well as posteriorly, and reduces the three other genitals to dimensions hardly greater than those of the *oculars*. These last are all five similar in form and size.

A feature of the system in *A. orbicularis* that appears in the moulds is the unequal thicknesses of the plates. The impressions of the oculars, and of the left anterior genital, are all shallow—in fact, at the same level as those of the coronal plates. But the other three genitals (the two postero-lateral and the madreporic plates) have left very much deeper scars on the mould, indicating their greater thickness. All the five specimens I have seen agree in this point, which, although of unknown significance, seems worth noting from its persistent occurrence.

In *Anorthopygus*, then, the cycle of the apical system is complete in form, but the posterior genital is missing, and the centre of the system is filled by the madreporite.

E. The Apical System of *Holectypus*.

As was the case in *Pygaster*, this genus is capable of division into two clearly defined groups on the structure of the apical system. These groups were named by Pomel (1883) *Holectypus* [*sens. str.*] and *Cœnholectypus*. Stratigraphically they are restricted to Jurassic and Cretaceous forms respectively. '*Holectypus*' has only four genital pores, while '*Cœnholectypus*' has five. This is not, perhaps, such an important distinction as some authors have considered, but, in view of the stratigraphic value of the distinction in this case, I think that Pomel's name *Cœnholectypus*, clumsy though it is, should be given at least a subgeneric sense for Cretaceous *Holectypi*.

1. *Holectypus, sens. str.* (Pl. II, Fig. 5.)

The most striking feature of the apical system in the Jurassic forms is the extreme prominence of the madreporite. This is central in position and dome-shaped. In *H. depressus* its prominence is perhaps more noticeable than in other species, but in *H. hemisphæricus* (where the whole system is not infrequently sunk below the level of the corona) it is still well marked. The water pores are, as usual, entirely restricted to the right anterior genital, which is therefore, as in *Pygaster, sens. str.*, very largely developed in its central extension. The full complement of five *genital plates* is present, and the posterior one, although imperforate, is often quite as large as the other three (ordinary) plates. The central development of the madreporite is so great that the *oculars*, no less than the genitals, are all in contact with it. In *H. depressus*, indeed, the oculars are almost of the same size as the genitals.

2. *Cœnholectypus*. (Pl. II, Fig. 6.)

The only constant difference in the apical system between this group and the last is in the perforation of the fifth genital. The size and position of the madreporite are similar in both divisions.

In *Holectypus*, '*sens. lat.*', then, we see a complete recovery of the apical cycle in shape and in composition, and the monopolization of the centre of the system by the madreporite.

F. The Apical System of *Discoïdea*. (Pl. II, Fig. 7.)

In the case of *Discoïdea* there are two variable characters in the structure of the system which seem to be quite casual in their occurrence. Even Pomel was unable to found 'generic' distinctions upon them; and, indeed, they may differ in individuals of the same species. The two characters are: the presence or absence of a pore in the fifth genital, and the restriction of the madreporite to its normal plate, or its distribution over all five genitals. (The perforation of the posterior genital is usual, though not invariable.) The irregularity of development of such seemingly important features, within the limits of an otherwise circumscribed genus, would appear to indicate clearly the plasticity of structure which is generally associated with the rapid differentiation of new types. *Discoïdea*, as

I hope to show in a future paper, is near the parting of the ways between some important lines of evolution, and the unstable characters of its apical system are indices of that fact.

The cycles of plates are always complete, the *genitals* being usually tumid and considerably larger than the oculars. Whether the madreporite is in its usual plate, or scattered over all five, the right anterior genital is never much larger than the other four. All genitals take an equal share in the occupation of the centre of the system. This uniformity in size of the genitals confines the *oculars* to a marginal position in the system, and, owing to their relatively small size, they play quite an unimportant part in the construction of the apical disc.

In *Discoïdea*, then, the cycle is complete, and the centre of the system is occupied by equal extensions of all five genitals. The madreporite may, or may not, be central.

G. The Apical System of *Conulus*. (Pl. II, Fig. 8.)

There is a curious diversity of opinion as to the composition of the apical system in this genus. Wright and Cotteau both describe it as having five genital plates, the posterior one being small and imperforate. This small plate would, by its presence, serve to distinguish *Conulus* from *Pyrina* (see Pl. II, Fig. 9). In spite of the figures given by these authors I have been unable to find any trace of a fifth genital, although I have examined several hundreds of specimens of the common British species. Even in cases of marked abnormality no plate in the position of the posterior genital has been distinguishable. It seems unlikely, however, that both these authorities can have been mistaken, so that it is probable that some specimens (of both *C. subrotundus* and *C. albogalerus*) possess the posterior genital. I think it is safe to assume this character to be exceptional, and that the great majority of individuals have only the four genitals. I shall only describe and figure here the type that I have seen.

The apical system is not quite circular, but tends to be elongated along the antero-posterior axis. The tendency is, however, very slight. The four *genitals*, taken together, build a roughly square figure, into the middle of three of the faces of which the anterior oculars are inserted. The madreporic genital is considerably larger than the others, and occupies most, but not all, of the centre of the system. It never quite separates the two postero-lateral genitals. The madreporite is normally restricted to the right anterior plate. (There is a specimen of *C. albogalerus* in the collection of Mr. Ll. Treacher, F.G.S., which, in addition to other slight abnormalities, has the madreporite on all four of the genitals.) In the absence of the fifth genital the two posterior *oculars* meet along the median line, and are of much greater size than the other three. They are sometimes of about the size of the non-madreporic genitals, but are usually smaller.

Conulus, then, shows the cycle completed by the large development of the posterior oculars, while the centre of the system is largely, though not entirely, occupied by the madreporite.

H. The Trend of Evolution of the System.

It seems advisable to explain that the evolution indicated here is not necessarily coincident with the phylogeny of the group, but applies only to the lines of development of the one structure.

The passage of the periproct out of the apical system resulted at first in the complete destruction of the posterior genital and a displacement of the remaining plates into a transverse rather than a radiating series. This is the stage represented by the '*Plesiechinus*' section of *Pygaster* (Pl. II, Fig. 1). Subsequent stages may be divided into two series: first, those in which the posterior genital was permanently absent, and second, those in which it reappeared.

The simplest condition of the first series is exemplified by *Anorthopygus* (Pl. II, Figs. 3 and 4). Here, after the complete separation of the periproct from the apex, the madreporic genital passed back through the system, which therefore becomes ethmolysian. This condition results in an apical system hardly differing from that of a Spatangid, as may be seen by comparing Figs. 4 and 11 of Plate II.

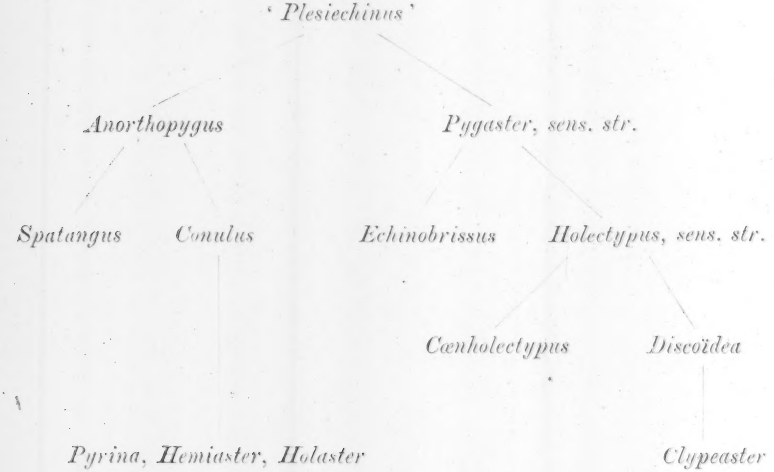
By a slightly different process the two posterior oculars, instead of being widely separated by the intrusion of the madreporite, became enlarged and met one another across the posterior margin. The two postero-lateral genitals followed them, and later the two antero-lateral oculars. The various stages in the consequent thrusting forwards of the madreporite are indicated by a comparison of Figs. 4, 8, 9, 13 (Plate II), treating them as a sequence. *Conulus* is the only true Holectypoid that shows this condition typically. It is, however, a very general one among Irregular Echinoids, as its presence in such widely differing forms as *Pyrina*, *Hemiaster*, and *Holaster* shows (cf. Pl. II, Figs. 9, 10, and 13).

The second direction of development commenced with the *Pygaster, sens. str.*, group (Pl. II, Fig. 2), where the place of the fifth genital was occupied by one or more small plates distinct from those of the anal membrane. In some forms, notably among the *Echinobrissi*, the presence of more than one of these posterior plates became common, though not universal. The madreporite is large and tends to occupy all the centre of the system. In *Holectypus, sens. str.* (Pl. II, Fig. 5), the posterior genital became single and imperforate (a condition often present in *Discoïdea*), and finally, in *Cœnholectypus* (Pl. II, Fig. 6), it became perforated, thus rendering the apical system complete.

As a variant from this *Holectypus* plan, in which the madreporic genital was much larger than the other four, we find the *Discoïdea* principle, in which the posterior genital (whether perforated or not) was, in common with the others, of practically the same size as the madreporic plate. The most significant change in this group was, however, the spreading of the madreporic water-pores over all five genitals, accompanied by the reduction in importance of the oculars. The natural outcome of such a process was the apical system of the Clypeastroids (Pl. II, Fig. 12), where, apart from the fusion of the genitals, the structure was quite similar to that of *Discoïdea*.

Finally, using the generic names merely to indicate types of

structure rather than true phylogenetic affinity, the tendencies of evolution of the apical system may be expressed in the following diagram :—



EXPLANATION OF PLATE II.

The figures are not drawn to a definite scale, and, except where otherwise stated, are generalized from several specimens.

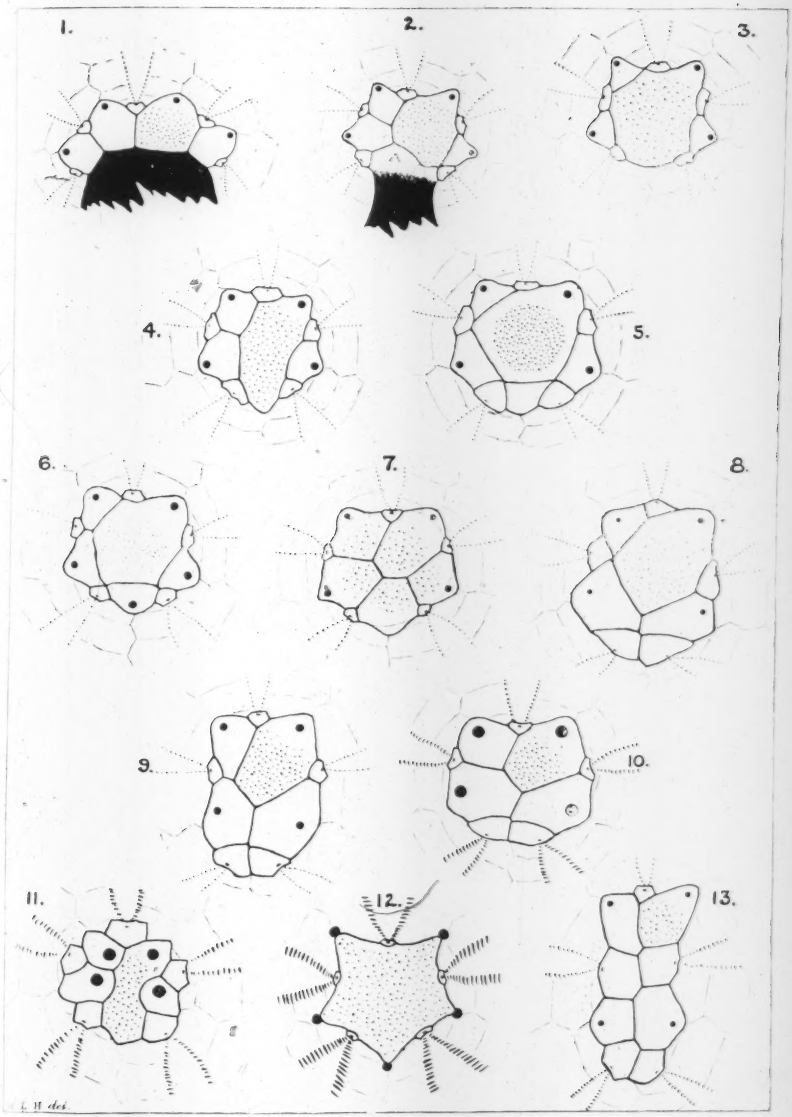
FIG. 1. Apical system of *Pygaster* ('*Plesiechinus*') *macrostoma* (after Wright).
.. 2. Apical system of *P.* ('*Pygaster*') *umbrella*.
.. 3. .. .. *Anorthopygus michelini* (after Cotteau).
.. 4. .. .. *A. orbicularis*.
.. 5. .. .. *Holectypus* (*Holectypus*) *depressus*.
.. 6. .. .. *H.* (*Cœnholectypus*) *cenomanensis* (after Cotteau).
.. 7. .. .. *Discoïdea cylindrica*.
.. 8. .. .. *Conulus albogalerus*.
.. 9. .. .. *Pyrina desmoulinsi*.
.. 10. .. .. *Hemiaster* or *Micraster*.
.. 11. .. .. *Spatangus*.
.. 12. .. .. *Clypeaster*.
.. 13. .. .. *Holaster* or *Echinocorys*.

V.—Outlines of Oilfield Geology.

By T. O. Bosworth, B.A., B.Sc., F.G.S.

Introduction.

IT is remarkable that in English geological literature and in our Universities so little attention is given to this important branch of geology. Probably it is because in this country petroleum occurs only in small quantity; nevertheless, in many parts of the British Empire petroleum mining has become a great and increasing industry, and is one of the chief directions in which geology is of practical



Apical Systems of some Irregular Echinoidea.

use to-day. The writer therefore hopes that an orderly summary of present knowledge may be useful.

Part I. Theoretical Considerations.

Origin.—Within a petroliferous formation as found to-day the oil is concentrated in certain positions in the most porous beds, whilst often the intervening rocks show little or no indication of oil. The origin of the petroleum has been much discussed, especially in American, Russian, and German literature.

The theories may be placed under two heads according to the supposed source of the carbon.

1. *Inorganic Origin.*—It is held that the oil has been introduced into the rocks from deep-seated sources in or beneath the earth's crust, where it was perhaps produced by chemical reactions between such substances as water, carbonates, carbides, carbon dioxide, etc., and some authorities maintain that the intrusion of hydrocarbons is one of the phenomena of vulcanicity, similar to the intrusion of igneous magma. For many reasons these theories have been rejected by the majority of 'oil-geologists', as they do not accord with the distribution of the petroleum.

2. *Organic Origin.*—It is held that the hydrocarbons have been produced by chemical changes in the organic matter present in the sediments. The organic origin is generally accepted, though there is much difference of opinion as to what animals or plants (terrestrial and marine) can give rise to petroleum and under what conditions.

The facts differ widely in different fields. In some the oil-rocks occur amidst thousands of feet of strata rich in marine fossils. In others they are amidst great thicknesses of shallow water, coastal or estuarine deposits, in which both animal and vegetable remains abound, e.g. Peru. Rich oil-sands are sometimes closely associated with coal-seams and lignites in formations where the organic matter apparently is mainly vegetable and terrestrial, e.g. in Assam. (Small quantities of oil have occasionally been met with in various British coal-fields.)[1] Again, in some fields the oil horizons are unfossiliferous sands separated and underlain by thousands of feet of clays and shales, most of which are entirely devoid of *visible* fossil remains, e.g. Trinidad.

In some fields the oil-rocks are associated with salt and gypsum, bearing formations from which the oil seems always to have originated, e.g. the Roumanian Oilfields. Yet again the oil-rocks occur in association with diatomaceous sediments. From such Dr. Ralf Arnold informs me there can be no doubt that much of the Californian oil has been derived.

It is supposed that the oil begins to form from the organic matter not long after deposition, as films and globules around and among the rock particles, accompanied by the salt water of sedimentation; but nothing definite is known as to the conditions of temperature and pressure necessary.

[1] Commercial quantities of oil from the Scottish Oilfield are not found present in the rocks as oil, but are produced on destructive distillation of certain carbonaceous shales.

With advancing age both temperature and pressure are increased owing to the deposition of sediments above, and at length the oil and salt water may be driven out and redistributed many times.

It is a remarkable fact, proved, in the Appalachian Oilfields at any rate, by innumerable deep borings, that as a rule the amount of water now present in the rocks decreases as depth increases. At great depths—several thousand feet—there is little or no moisture, even in porous sandstones, and the rocks are ready to absorb large quantities of water. At more moderate depths there is a little water and that is generally saline, whilst only at comparatively slight depths are the strata thoroughly invaded by fresh water from above. Generally, the further we explore a stratum down the dip the less is the volume and the greater the salinity of the water found.

How these rocks have lost their original water of sedimentation is not known, but perhaps it was expelled at a time when they were hotter or more compressed. All sedimentary rocks are to some extent porous, and at depths where they are thus dry, capillary action would exert a great influence on the movement of any fluid invading the strata or already imprisoned there. Capillary action has probably played an important part in the process by which the oil has been leached out of the beds of clay and shale.

The principal forces which have controlled the movements and ultimate position of the oil are—

1. *Vapour Tension* (*Gas Pressure*).—Commonly the pressure on the gas and oil is found to be far too great to be due to any hydrostatic pressure communicated to them, and it would seem that additional pressure has been and is being generated in situ. Such a change of vapour tension of the fluid may be brought about by chemical alteration still taking place. Similar changes in vapour pressure, due to chemical or thermal alterations, may have occurred often during the past history of the oil and have disturbed the equilibrium from time to time. The gas pressure, being equal in all directions, simply tends to force the oil out along any line of weakness.

2. *Capillary Action.*—This acts differentially among the strata and tends to produce motion in particular directions depending on the characters of the rocks. It is probably most effective at depth during the earlier history of the oil.

3. *Gravitation.*—In *dry* rocks gravitation imparts a downward motion to the oil, which seeks the lowest places in the containing stratum. In *wet* rocks gravitation tends to send oil upwards, for the fluids must arrange themselves in order of density—water at the bottom, oil resting on it, and gas occupying the space above. Where hydrocarbons are entrapped over water the water may impart a considerable hydrostatic pressure. The gravitation effects are the most important in determining the present position of the oil in most fields.

Under the action of these various forces the hydrocarbons have been leached out of clays and shales, and have undergone a very complicated history of movements, to and fro, through and among the rocks. A large amount of hydrocarbons is ever escaping into the atmosphere, whilst always considerable quantities remain temporarily entrapped.

Part II. The Accumulations of Petroleum.

Next will be given an epitome of the circumstances which are found to have been favourable to the accumulation of petroleum.

The chief rocks in which the entrapped oil finds accommodation are beds of uncemented sandstones and dolomitized limestone. Of these the oil sandstones are the more usual, but oil in dolomites is also common, e.g. in the Palæozoic oil-formation of the United States and Canada and in the Tertiary oil-rocks of Mexico. Other porous rocks occasionally contain oil, e.g. tuffs and much jointed shales.

Practical men have often classified the occurrences into two divisions—

Oil in anticlines.
Oil in monoclines.

The latter term has been used to include almost all cases where the oil strata are not now in the form of an arch (which was once thought to be essential). To geologists this is unsatisfactory, because the 'monocline' is so often simply one limb of a denuded anticline.

Here the accumulations will be classed in three main groups, according as they have been determined by—

A. Geological Structure.
B. Denudation Effects.
C. Petrographical Circumstances.

A. Oil Accumulations determined by Geological Structure.—Where the strata are not horizontal the geological structure has been the main factor in deciding the distribution of oil. Under the action of gravity oil tends to move upwards in wet rocks and downwards in dry rocks, and accumulation takes place wherever the geological structure provides an obstruction or a terminus to the path in which the oil is moving.

1. *Terrace Structure.*—Many varieties of this structure occur in the oilfields of Kentucky, East Ohio, Pennsylvania, New York, and West Virginia.

Fig. 1. Oil accumulation due to terrace structure. Sandstone, dotted; oil, black.

The strata have a prevalent slight dip in one general direction, but here and there the dip abruptly increases or decreases for a short distance and then continues as before. Often where these terraces are narrow and almost horizontal, accumulations of oil and gas are found. It would seem that the oil has been migrating in one direction—up the dip if the rocks contain water, or down the dip if they be dry—and that any sudden change in the inclination of the beds (especially a diminution) has acted as a slight check, causing local accumulation (Fig. 1).

2. *Undenuded Folds.*—In general, water, oil, and gas are all present in the porous oil-bed, and under the action of gravity arrange themselves vertically in order of density.[9] Hence the gas will occupy the crests of anticlines, whilst the oil will be found in the limbs of the folds resting on the water, which will occupy the remaining space below (Fig. 2*a*).

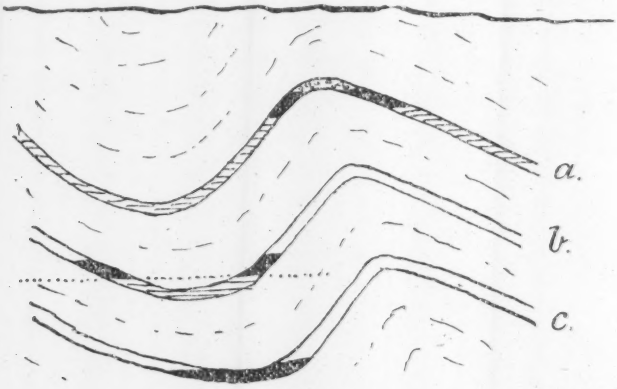


FIG. 2. Oil accumulated in undenuded folded beds. *a* = bed saturated with water; *b* = bed saturated with water up to a level shown by dotted line; *c* = bed containing no water. Oil shown black; gas under pressure shown by small circles; water shown by horizontal lines.

The heights of the oil will depend upon two factors: it will be in equilibrium under—

(1) The gas pressure generated—keeping it down.
(2) The hydrostatic pressure—keeping it up.

If there is no gas, oil will occupy the crest of the anticline. And if there is no water, oil will occupy the syncline. The wells must be placed accordingly.

A certain amount of *gas* is present in most fields, and in some cases there is such great quantity that it is exploited independently by wells on the anticlinal crests, as in some of the Pennsylvanian and West Virginian Fields and the Surakhany gas-field near Baku; often a single well will yield ten million cubic feet of gas per day, and when the well is closed a pressure of thirty to forty atmospheres may be registered. *Water* usually is present, and therefore the oil is found in quantity only at or near the crests of the folds. Sometimes, however, the porous rock contains only sufficient water to saturate it up to a certain level, in which case the oil is not forced so far up towards the crest whether there be much gas pressure or no (Fig. 2*b*). The Gordon sand in Pennsylvania is an instance.[1]

Oil in synclines is not common and rarely is present in commercial quantity, but occasionally in the absence of water considerable quantities have accumulated (Fig. 2*c*). Instances are cited in the Californian Fields.

The shapes of oil-bearing folds are very varied. Some are

[1] Bull. No. 318, U.S. Geol. Surv., 1907, p. 16.

symmetrical (e.g., Yenangyaung Oilfield, Burma), others have the axial plane inclined. In some fields, Trinidad for instance, the crests are sharp and narrow and may be only two or three miles apart, whilst in others they undulate so gently that the dip seldom exceeds a few degrees, and some oil-bearing folds are broad geo-anticlinals many miles across (in the United States).

Usually the anticlinal axis is not horizontal, but rises and falls repeatedly. This doming of the anticline causes such special concentration at the domes that sometimes the intervening parts of the anticline are barren.

When an anticline is asymmetrical the gentler slope generally provides the best well-sites, and gentle anticlines are usually more prolific than steep ones; indeed, many of the richest fields are on anticlines whose flanks slope at only a few degrees and whose crests are very broad. On very broad anticlinals, several miles across, the hydrocarbons are often concentrated in isolated pools where the circumstances are particularly favourable. Variation in porosity and bedding, faults, minor wrinkles on the fold, etc., have been important in determining these sites.

3. *Salt Domes* (*'Salines'*). — These remarkable structures are abundant in the oilfields of the Gulf Coastal Plane in Texas and Louisiana (Fig. 3). Sometimes the domes are of such recent elevation that they show as circular hillocks at the surface, hundreds or thousands of acres in extent, and upwards of 100 feet in height.

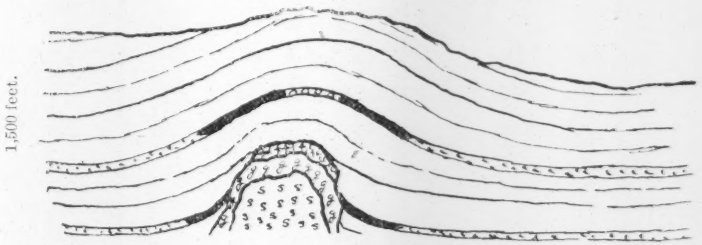


FIG. 3. Oil accumulation caused by a salt dome. Salt intrusion, *sss*; gypsum intrusion, *ggg*; dolomite intrusion, †††; sandstone bed, dotted; oil, black; gas shown by circles.

At depth beneath the upraised strata is found a great plug of crystalline salts which in some cases has burst right through the strata and reached the surface. The chief salts are sodium chloride, gypsum, and dolomite, which occur in ascending order. It is supposed that these have been precipitated from hot saturated solutions circulating below, and that the domes have been raised by the force of crystallization.

The domes apparently occur at places of weakness, such as the intersection of faults. Porous sandstones in such domed Tertiary strata form ideal sites for the accumulation of oil, and have yielded great quantities.

4. *Strata upraised by Igneous Intrusions.*—Probably this case is more common than is yet proved, for many domes and anticlinals may at depth be underlain by laccolitic or other intrusions (though if this

be so it would still be difficult to discriminate between the fold and the intrusion as to cause and effect).

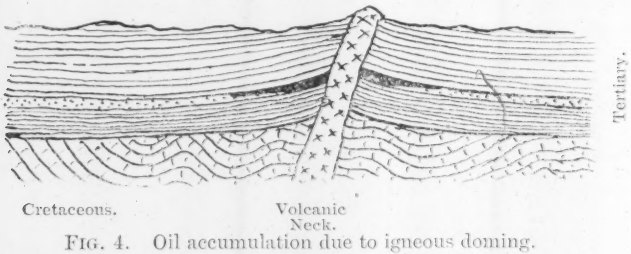


FIG. 4. Oil accumulation due to igneous doming.

In Mexico there are numerous volcanic necks which have burst through Tertiary strata, raising them and producing a dome-like structure around each core of igneous rock, and thus forming very favourable conditions for the concentration of oil in the sands (Fig. 4).

5. *Inclined Strata intersected by Dykes.*—In the same area dykes intersect the strata and sometimes act as dams to the oil ascending an inclined sandstone bed (Fig. 5).

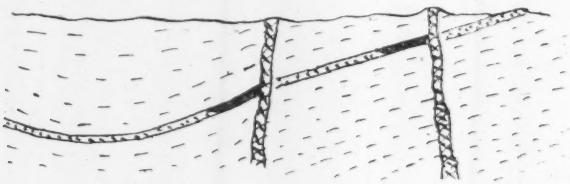


FIG. 5. Oil accumulation in a sand where dammed by dykes.

6. *Fault-sealed Oil-rock.* — Often oil ascending along an inclined porous bed is prevented from escaping at the surface by a fault which has displaced the outcropping portion and substituted impervious clays (Fig. 6).

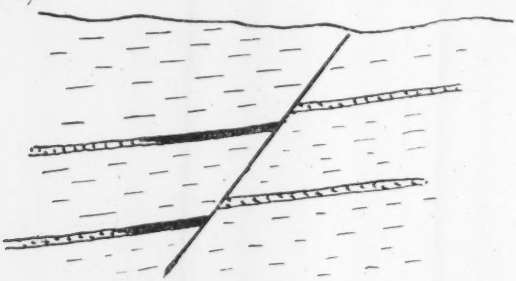


FIG. 6. Oil accumulation in porous beds dammed by a fault.

Sometimes a whole row of wells has been placed alongside such a fault. A notable example is the Western Coalinga Oilfield, Los Angeles, California, but the case is quite common in many fields in combination with other structures, and many a big well may owe its success to the sealing effect of a small fault.

7. *Porous Strata Thrust over a folded Oil-generating Formation.*—This important class includes a variety of complicated structures, from some of which great quantities of oil have been obtained. The circumstances belong to regions of intense folding, and are best illustrated by the oilfields of Roumania, where they are well known.

In Roumania the source of oil appears to be the saliferous formation, and the places where the oil is concentrated lie along important lines of thrust-folding—"places where there has been maximum pressure and minimum resistance."[1] Along these lines occur very 'pinched' anticlines and overfolds with much overriding of one formation upon another. The saliferous formation contains hard massive salt rock and often forms the core of the fold, in which case oil is generally found.

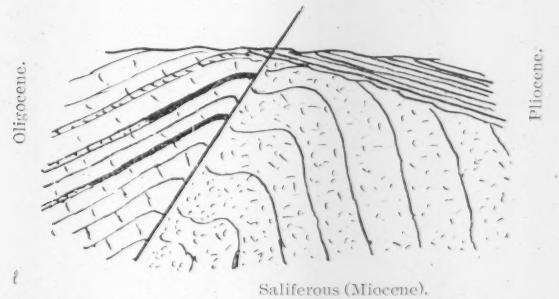


FIG. 7. Oilfield at Bushterrari. Oil derived from upfolded saliferous Miocene, but accumulated in overfolded Oligocene.

The oil, however, is not concentrated in the saliferous but in the porous beds of the older (Oligocene, Fig. 7) or newer (Pliocene, Fig. 8)

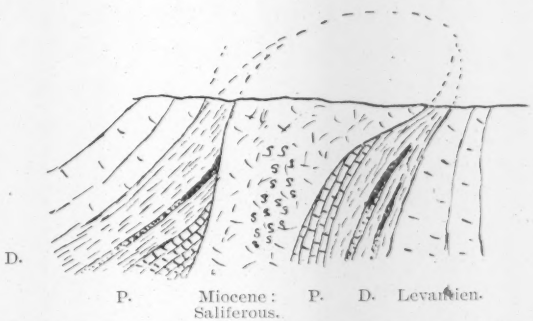


FIG. 8. Oil derived from upfolded saliferous Miocene, but accumulated in contiguous Dacien (D.). Oilfield at Bacoi (diagrammatic section). *sss* indicates masses of rock-salt. P. = Pontien; D. = Dacien.

formations thrust over it or faulted against it. The conditions are very favourable, viz., compression of the oil-generating rocks, relief of pressure above, contact with overlying porous beds, the porous beds inclined and generally sealed at their upper ends.

[1] Professor Mrazec, "Excursions dans les regions pétrolifères de la vallée de la Prehova," p. 62. Congrès International de Pétrole, 1907.

(To be concluded in our next Number.)

VI.—The Rhætic Rocks of Warwickshire.[1]

By L. Richardson, F.R.S.E., F.G.S.

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I. Introduction.

THE distribution of the Rhætic rocks in Warwickshire is not represented on the existing Geological Survey maps because at the time that the survey was made their distinctness from the Lower Lias was not appreciated, and therefore they were represented by the same colour.

In Warwickshire, as in other counties, the Rhætic beds crop out at or near the top of an escarpment, which, as a rule, is very well marked and oft-times really steep. But in the extreme north-eastern portion of the county the usual escarpment is buried beneath a thick accumulation of drift; while from one or two places in the neighbourhood of Stratford-on-Avon it is absent, because the boundary-lines are faults.

The geologist who has contributed most to our knowledge of these beds in Warwickshire is undoubtedly Brodie. From the bottom-beds of the Lias in the county he collected many insect-remains[2]; he described the sections of Rhætic beds on the railway at Summer Hill, near Bidford,[3] and between Ettington and Kineton[4]; he found indications of the Bone-Bed equivalent (in the form of a thin yellow sandstone band crowded with casts of '*Pullastra*') at Knowle, near Birmingham[5]; and obtained most interesting pieces of richly-fossiliferous *Peeten*-Limestone and *Estheria*-Bed from the outliers near Wootton Wawen.[6]

Brodie is followed by Mr. H. B. Woodward, who has noticed the sections at Harbury[7] and Church Lawford,[8] and by the late R. F. Tomes, who collected many fossils from the White Lias of the county.[9] Others who have contributed to our knowledge of the beds in various ways are H. H. Howell,[10] T. Wright,[11] J. W. Kershaw,[12] J. M. Wilson, E. Cleminshaw, and Mr. F. T. Maidwell.[13]

[1] I have to acknowledge my indebtedness to the Government Grant Committee of the Royal Society for assistance towards carrying out the investigations that have resulted in this paper.

[2] *A History of the Fossil Insects in the Secondary Rocks of England*, 1845, pp. 73–9; Trans. Woolhope Nat. F.C., vol. for 1866 (1867), pp. 205–15, etc.

[3] Quart. Journ. Geol. Soc., vol. xlii, pp. 272–5, 1886.

[4] Ibid., vol. xxx, pp. 746–8, 1874.

[5] Ibid., vol. xxi, pp. 159–61, 1865.

[6] Ibid., pp. 160–1.

[7] *The Jurassic Rocks of Britain—The Lias of England and Wales (Yorkshire excepted)*, vol. iii, pp. 151, 159, 160, 1893: Mem. Geol. Surv.

[8] Ibid., pp. 151, 162, 163: Explanation, Hor. Sect., Sheet 140, p. 9.

[9] Q.J.G.S., vol. xxxiv, pp. 179 et seqq., 1878; vol. xl, pp. 353–75, 1884.

[10] *Geology of Warwickshire Coal-field*, 1859, p. 45.

[11] Q.J.G.S., vol. xvi, pp. 394, 395, 1860; Pal. Soc., Monogr. Lias Amm. Brit. Isles, pt. i, pp. 19–21, 1878.

[12] An active local geologist who furnished several authors with valuable information.

[13] Proc. Warwick. Nat. and Arch. F.C., 51st Ann. Rep., 1906, pp. 20–7.

Several observations that have been made by previous workers suggested that an examination of the Warwickshire Rhætic would be attended by more than ordinary interest. The three main observations are in effect—

(*a*) The record of a peculiar bed, called the 'Guinea-Bed', at the very base of the Lower Lias, which, from its lithic and faunal characters, suggests a non-sequence between Lias and Rhætic.

(*b*) That the White Lias proper is present in the county and in places arenaceous.

(*c*) That, in addition to the White Lias being arenaceous, the Black Shales are in places wanting, and that these facts lead to the conclusion that we are not far from the local margin of the deposit.[1]

It may be as well to state at once that the component divisions of the Rhætic Series in Warwickshire are not subject to the considerable changes that the foregoing remarks on their supposed arenaceous and attenuated condition would lead one to suppose. In brief, the Tea-green Marls of the Keuper are the same as usual; the Black Shales are probably continuous through the county (although more deficient in hard bands than usual); the greenish-grey marls of the Upper Rhætic are well-developed, in places containing an *Estheria*-Limestone rich in the characteristic phyllopod; while above, from the neighbourhood of Wimpstone Field north-eastwards to the county-boundary, is White Lias—unmistakable, both as regards its lithic characters and fossil contents. Indeed, this presence of true White Lias (Langport Beds) is the most interesting feature of Warwickshire Rhætic stratigraphy.

In the neighbourhood of Binton, Grafton, Wilmcote, and Bickmarsh, from which, however, the White Lias is absent, occurs the 'Guinea-Bed'. This is a peculiar and frequently conglomeratic stratum, its lithic and faunal characters indicating a non-sequence between it and the immediately subjacent deposit. Some authors have grouped the bed with the Rhætic, others with the Lias, but fuller reference will be made to this matter later.

Above the Guinea-Bed come the alternating deposits of limestone and clay in connexion with which the terms 'firestones', *Ostrea*- and Saurian Beds, and Insect Beds are familiar.

Tea-green Marls.—The line of demarcation between the Tea-green Marls and the Black Shales at the few places where I have seen their junction, and from all accounts, is sharply-defined, and no representatives of the Sully Beds have been or, I think, are likely to be found.

The Tea-green Marls themselves, as already remarked, are of the usual type. Since at one end of the county, namely, at Marl Cliff, they are about 24 feet thick, and at Wigston in Leicestershire, beyond the northern end, about 15 feet thick, it is to be presumed that in the intervening district their thickness lies between these two figures.

There are no good exposures of the Tea-green Marls now available; but I have noted exposures of minor importance at the following localities:—

[1] *The Jurassic Rocks of Britain—The Lias*, etc., p. 151.

(1) Marl Cliff.
(2) Half a mile north of Billesley.
(3) A mile and a half 3° S. of W. of Bearley Junction.
(4) Near Whitehall Farm.
(5) At Atherstone Hill, near Preston-on-Stour.
(6) At Loxley.
(7) At Red Hill, to the north of Ettington Station.
(8) At Chesterton Green, near Harbury.

II. Subdivisions of the Rhætic Rocks recognizable in Warwickshire.

Black Shales or Westbury Beds.—There is now no good exposure of these Black Shales in the county; but a number of sections have been available from time to time when the railways were in course of construction.

From what has been recorded and from specimens that have been obtained, especially from Summer Hill, it is obvious that at certain horizons they are extremely rich in fossils, particularly in specimens of *Pteria contorta* and in species belonging to the genus *Isocyprina*. Hard beds do not seem to be prominently developed; but a number of thin sandstone-layers are reported to occur in the lower portion of the Black Shales in the Summer-Hill railway-cutting; while Brodie obtained numerous masses of highly-fossiliferous *Pecten*-Limestone from temporary excavations at Brown's Wood, which is situated 3½ miles to the west of Bearley Junction. The Bone-Bed, as a stratum rich in vertebrate-remains, appears to be very poorly developed. The only record of it, apparently in its typical condition, is one by Strickland, who observed it, *in situ* it is said, somewhere in the neighbourhood of Bidford.[1] In what is probably its usual condition in Warwickshire, namely, a yellow micaceous sandstone, it has been observed at Knowle and in the railway-cutting near Kineton.

It has not been possible, owing to lack of sections, to determine the precise thickness of the Black Shales. At Dunhampstead, in Worcestershire, they are about 18 ft. 6 in. thick, and at Wigston, near Leicester, 29 ft. 9 in. In Warwickshire it is to be presumed that their thickness lies between these figures, and in my opinion there is no reason for believing that they are absent from anywhere—not even from the Church Lawford neighbourhood.

The sharp line of demarcation between the Black Shales and Tea-green Marls is *ipso facto* suggestive of a non-sequence, and at Snitterfield, near Stratford, Brodie, as long ago as 1886, thought he had evidence that indicated that the Tea-green Marls had been subjected to erosion previous to the deposition of the Black Shales. Be this as it may, the lower limit of the Black Shales in Warwickshire is everywhere, as far as we know, 'sharply-defined.'

This, however, is not the case with regard to the upper limit of the Black Shales, for they merge into the greenish-grey marls of the Upper Rhætic.

Cotham Beds.—These deposits are almost wholly marl of the usual greenish-grey tint, and are continuous throughout the county. No stratum exhibiting Cotham-Marble facies has been detected; but the

[1] Q.J.G.S., vol. xxi, p. 160, 1865.

Estheria-Bed is present; has been proved in a sinking through the floor of a quarry at Wilmcote, near Stratford-on-Avon; and nodule-shaped masses of the usual type, rich in specimens of *Estheriæ*, have been obtained from Brown's Wood, near Wootton Wawen.

Langport Beds.—It is extremely interesting to find the White Lias proper present in Warwickshire, for after leaving the southern portion of Gloucestershire it is not seen again in its typical form until the neighbourhood of Wimpstone Field, near Stratford-on-Avon, is reached. Thence, right through to Rugby, it is well and persistently developed (maximum about 10 feet), of very much the same appearance as the Somerset White Lias, contains specimens of *Dimyodon intustriatus* (Emmr.) abundantly in places, and not infrequently corals. Certain of its beds are well-bored by annelids, and at Church Lawford portions are pebbly; while in the same neighbourhood it has a ferruginous deposit on top, with which are associated ample indications of erosion by water: in other words, there is abundant evidence for a non-sequence between the White Lias and the superincumbent Lower-Lias deposits.

The White Lias is absent from the neighbourhood of Binton, Grafton, Wilmcote, and Bickmarsh, being "represented", according to Mr. H. B. Woodward, "by the Guinea-Bed."[1]

No sections in which the Guinea-Bed is seen *in situ* are now available; but from a study of the recorded observations of previous workers I am certainly inclined to regard it as the bottom-layer, in the district mentioned, of the Lower Lias.

Lower Lias.—Above the Guinea-Bed come the numerous beds of limestone and clay from which abundant specimens of *Ostrea liassica*, insects, fish, and Crustacean remains have been recorded, and which are known as the 'Firestones' or '*Ostrea*-Beds'[2] and the 'Insect' or 'Saurian Beds'.[3] *Ammonites planorbis* and *A. johnstoni* appear to range throughout. This is puzzling; but apparently, whilst the beds that are richest in insect and Crustacean remains in Somerset come *below* the limestones that contain *Ostrea liassica* in greatest abundance, in Warwickshire they come *above* and are of *planorbis* date.

The interesting point in connexion with the deposits in the neighbourhood of the junction of the Rhætic and Lias beds in Warwickshire is that while the Firestones or *Ostrea*-Beds, Saurian or Insect Beds are present in the district in which the Guinea-Beds occur (and from which the White Lias is absent), they are absent

[1] *The Geology of England and Wales*, 1887, p. 247.

[2] Brodie states (Trans. Woolhope Nat. F.C., vol. for 1866, p. 212) that it is worthy of note that in one of the more westerly sections at Wilmcote "all the insect beds thin out and scarcely amount to three layers, the top band being irregular and shattered; a thick mass of shale succeeds, undivided, as elsewhere, by limestones, and below are three beds of limestone, viz., the firestone, with *Ostrea liassica*, but of a very different character". From Brodie's record of the Wilmcote section (*loc. cit. supra*, pp. 210–11) it is clear that the limestones in which he found insect-remains most abundantly came *above* the deposits in which saurian-remains are commonest, and are clearly of *planorbis* date.

[3] Brodie complains that his name of "Insect Beds" was ignored by Wright, who applied the term "Saurian Beds" to them (Trans. Woolhope Nat. F.C., vol. for 1866 (1867), p. 210).

from the greater portion of Warwickshire where the true White Lias occurs. There stiff, blackish clays rest directly upon the White Lias.

III. Local Details.

At Marl Cliff the Tea-green Marls are visible, then about 2 feet of black shale, to which follows a layer of sandstone, 1 inch thick, that represents the Bone-Bed.[1]

Summer Hill.—Here the East and West Junction Railway passes through the escarpment of the Rhætic beds in a cutting. When this railway was constructed an excellent section was displayed; but while Brodie has furnished some information, it is unfortunate that his remarks were not more detailed.[2]

According to Brodie, the beds dip to the south-east. At the eastern end of the cutting was an "insect-limestone, probably the bottom one of the series", below which came, in descending order, the Firestone, the *Estheria*-Bed (doubtless embedded in the usual greenish-grey Upper-Rhætic marls), and then the Black Shales. The Black Shales were, in the words of Brodie, "loaded with the usual characteristic fossils" at certain horizons;[3] but whilst he noticed a "band of blue nodular stone in the shales", which probably represented the *Pecten*-Bed, he did not observe any equivalent to the Bone-Bed. Probably it was present as a thin sandstone-layer, like its representative at Marl Cliff and Knowle, near Birmingham.

The escarpment between Summer Hill and the neighbourhood of Newnham is well-marked and in places very steep, but there are no exposures of the Rhætic beds in it.

North-west of Newnham, but on the opposite side of the Alne River, are two outliers of Rhætic beds, namely, those called by Brodie 'Stooper's Wood' and 'Brown's Wood'.

Stooper's Wood Outlier.—This outlier is composed of Rhætic and Lower-Lias beds. The quarry referred to by Brodie at Shellfield is overgrown now, and those from which he obtained evidence of the *Pecten*- and *Estheria*-Beds, the latter containing fragments of *Lycopodites*, were characterized as 'old' by Brodie as long ago as 1865.[4]

Brown's Wood Outlier.—Brodie noticed beds similar to those he saw at Stooper's Wood at Brown's Wood.[5] The 'Insect-Limestones' appear to have been singularly fossiliferous, containing

"a great variety of beautifully-preserved insect-remains . . . a few fragmentary plants (including fronds of fern), and a small shrimp-like Crustacean . . ."

Similarly, the *Pecten*-Bed proved to be highly-fossiliferous, and some of the well-preserved specimens referred to by Brodie[6] are now to be seen in the Warwick Museum. There is also, from the same locality, a piece of limestone crowded with specimens of *Estheria minuta* var. *brodieana*.

[1] L. R., Proc. Cotteswold Nat. F.C., vol. xv, pt. i, p. 41, 1904; Trans. Worcestershire Nat. Club, vol. iii, p. 101.
[2] Q.J.G.S., vol. xlii, pp. 272–3, 1886.
[3] Amongst them *Ophiolepis damesi*. Examples of *Isocyprina* spp., *Pteria contorta*, *Natica oppeli*, etc., in black shale from here are exhibited in the Warwick Museum.
[4] Q.J.G.S., vol. xxi, p. 160, 1865.
[5] Ibid., p. 160.
[6] Ibid., vol. xxx, pp. 748–9, 1874.

Copt-Heath Outlier, near Knowle.—This outlier is composed of Rhætic and basal Lower-Lias deposits. It was discovered by Dr. Lloyd, of Leamington, but was first referred to in print by Strickland[1] and noticed in greater detail by Brodie.[2]

The Lias beds on the occasion of Brodie's first visit were reached by means of a shaft, but from the rock that was excavated Brodie was enabled to determine the presence of the zone of *Ammonites planorbis* and of the Saurian and *Ostrea*-Beds with the usual fossils, but not the Insect Limestone. Traces of the *Pteria-contorta*-Shales were detected and also fragments of a yellow micaceous sandstone with '*Pullastra arenicola*', the equivalent of the Bone-Bed. Subsequently, in 1874, Brodie recorded that he had actually discovered the Insect Limestone, with insect-remains, but was unable to ascertain if there were several beds or only one.[3]

At the present time the spoil of Lower-Lias rocks at the old quarry and a great heap of black shale alongside the canal (which was dug out of it) are all that can be seen, but it is to be hoped that if any building-operations are carried out a sharp watch will be kept for possible exposures.

Wilmcote.—About fifty years ago (about 1860) Kershaw, of Messrs. Greaves & Kershaw, had a sinking made through the floor of one of the quarries at Wilmcote. The 'Firestones' were the lowest beds ordinarily exposed in the quarry, but by the sinking the following beds were proved :—[4]

			ft.	in.
	Lower Lias	28. Shale, hard, dark, slaty	1	0
		29. Guinea-Bed. Limestone, hard, shelly	0	1
Rhætic.	Cotham Beds	30. Shale, green, clunchy	3	0
		31. *Estheria*-Bed. Marl, fine-grained, greenish; *E. minuta*, var. *brodieana*	0	3
	Westbury Beds	32–42. Shales, black, with septaria at 19 ft. 9 in. down	26	2
	? T.-g. M.	"43. Clay, light, soft brown."		

Wright, who was the first to publish details of this section,[4] gave bed 30 to the "*O. liassica* and Saurian Beds", calling those from 31 to 43 inclusive the "Westbury Beds".

In his *Geology of Oxford* (1871) Phillips reproduces Wright's record from beds 28 to 43 (incl.). But while on p. 105 he groups bed 30 (some "green clunchy clay") with the Rhætic, on p. 110 he places it above the 'Westbury Shales', apparently regarding it as Liassic. There is little doubt that it belongs to the Cotham Beds, that is, to the Upper Rhætic.

Binton.—In a quarry at Binton, now overgrown, Tomes obtained a very interesting assortment of fossils from the Guinea-Bed. It included the tooth of the essentially Rhætic fish *Sargodon tomicus*, along with characteristic Lower-Lias fossils.

[1] *Memoirs of H. E. Strickland*, by Sir William Jardine, 1858, p. 117.
[2] Q.J.G.S., vol. xxi, pp. 159–60, 1865; Rep. Brit. Assoc., 1864, p. 52.
[3] Ibid., p. 748; see also *The Jurassic Rocks of Britain—The Lias*, etc., p. 153.
[4] Wright, Q.J.G.S., vol. xvi, pp. 385–7, 1860.

Some distance away to the west, somewhere in the escarpment, Tomes discovered a number of Rhætic beds. Wright published Tomes's notes in 1860[1] and reproduced them in his monograph in 1878.[2] In the same year, however, Tomes had occasion to publish the details with which he had furnished Wright; but he made some additions which are very helpful.[3]

Snitterfield.—Brodie, as already mentioned, thought there was evidence in a section displayed in an excavation made in connexion with the waterworks at Snitterfield that the Black Shales rested upon an eroded surface of the Tea-green Marls;[4] but while this may have been the case, doubt has been expressed,[5] and the observation had better not be made use of.

To the south of Stratford-on-Avon the White Lias first appears as rubble on the fields half a mile or so to the south-east of Sweet Knowle; then in a pond-side and in shallow abandoned workings on Wimpstone Field; and next, below the Lower-Lias limestones at Newbold Limeworks. The rock is of a pinkish-grey colour, often 'flinty', has corrugated and waterworn surfaces, and is often pierced by annelid-borings. Ferruginous matter, now oxidized brown, often occurs in the borings and fissures in the stone. Fossils are not numerous in this neighbourhood. An indeterminable species of *Isocyprina* is the most abundant form, and radioles of *Pseudodiadema* and valves of Ostracoda occur sparingly.

White Lias has also been worked at Armscote, on Meer Hill, and extensively at Red Hill and Oakham (to the north of Ettington Station), and is now quarried close to the station.

On the western side of the Dene Valley, that is, between Red Hill and Ettington Station, the White Lias occurs over a considerable area originating noticeably flat ground. The White Lias thence spreads round across the brook and railway, and pursues a north-easterly course to Lighthorne, having been in the past extensively quarried near the barn north of Stamford Hall, at Foss Farm, on Friz Hill, Moreton Hill, near Newbold Barn and Lighthorne itself, and is at present worked on the north side of Compton Verney Park and at Shadwell Barn, the latter the best section in the district.

In all these sections the White Lias is very similar in appearance, much resembling the Somerset White Lias. In places it is rich in specimens of *Dimyodon intusstriatus* and *Pseudomonotis fallax*, while ostracods and broken radioles of *Pseudodiadema* are not uncommon. The beds are between 6 and 10 feet thick, and most of the component layers are bored by annelids and oft-times have well-waterworn surfaces encrusted with the characteristic *Dimyodon*, facts denoting slow formation.

In a quarry near Compton Park tough black clay, familiar in sections further north, occurs immediately above the White Lias.

[1] Q.J.G.S., vol. xvi, pp. 394–5, 1860.

[2] Pal. Soc., Monogr. Lias Amm. Brit. Isles, pt. i, pp. 19–21, 1878; see also Phillips, *Geology of Oxford*, pp. 111–12.

[3] Q.J.G.S., vol. xxxiv, pp. 181–2, 1878. Strickland discovered the Bone-Bed *in situ* at Temple Grafton (Brodie, *Fossil Insects*, p. 73).

[4] Ibid., vol. xlii, pp. 273–4, 1886. [5] Discussion, ibid., pp. 274–5.

It is interesting to find this clay thus far south in immediate contact with the White Lias, for I think there is no doubt that the deposits are non-sequentially related, that the Insect and associated beds, to say the least, are absent from in between.

Abundant evidence of the White Lias is to be obtained in certain of the railway-cuttings between Ettington and Kineton, along with the underlying Upper-Rhætic greenish-grey marls, in which, in the cutting nearest the River Dene, Brodie discovered the *Estheria*-Bed. In the same cutting he noticed the *Pteria-contorta*-Shales below, and in that near Butler's Marston the *Estheria*-Bed and greenish-grey marls and

> "about twenty feet of black shale . . . at the west end of the cutting overlain by drift. Further on, beyond the ridge nearest to Kineton, these black shales (*Avicula contorta* zone) may be traced, having included fragmentary pieces of yellow micaceous sandstone, the *Pullastra arenicola* bed . . . The White Lias is again exposed in the section beyond, broken up on the top, underlain by the '*Estheria*-bed' ".

The White Lias has been extensively worked in the past at Sitch Field, on the outlying Barn Hill, while there are two quarries at present in work near Chesterton Church. In the neighbourhood of Chesterton Windmill are numerous small openings in the White Lias, but the best is that situated a quarter of a mile to the north of the windmill.

The quarry referred to is on a line of fault and the beds are much disturbed. At the top are the tough blue Lias clays, then the rusty layer, followed by 6 to 8 feet of White Lias, and lowermost some greenish-grey marls (Cotham Beds). The surfaces of most of the limestone-beds are waterworn, some are bored by annelids, and many have specimens of *Dimyodon* adhering.

Harbury.—At Harbury the Rhætic escarpment is traversed by a deep railway-cutting. The only rock well exposed is the White Lias.

The Red Keuper Marls are seen in the brook-sides near the level-crossing at the western end of the cutting; the Tea-green Marls succeed and are followed by the *Pteria-contorta*-Shales, which, however, are only seen in the form of material worked out by the rabbits. The greenish-grey marls of the Cotham Beds are similarly exposed, and, for them, are of considerable thickness. The White Lias is very conspicuous and forms an inclined bench on both sides of the cutting. The upper beds, as usual in Warwickshire, are more massive than the lower. The top-layer has a waterworn surface, is iron-stained and crowded with fossils, particularly with specimens of *Isocyprina*.

Other fossils from the White Lias here are *Dimyodon intusstriatus*, *Plagiostoma valoniense*, *Pleuromya crowcombeia* auctt., *Pseudomonotis*, *Plicatula* cf. *cloacina*, Vaughan, *Volsella minima*, Moore *non* Sow., *Montlivaltia tomesi*, *Pseudopedina tomesi*, and Ostracoda.

The tough blue clays of the type common to the base of the Lower Lias in this part of Warwickshire succeed and are followed by the *Angulatus*-Beds, which are rich in pyritized specimens of *Schlotheimia*. No indications of the *Ostrea*- and Insect Beds have been observed, and the *Planorbis*-Beds, if present, are represented by clay or shales.

Mr. H. B. Woodward has briefly noticed this section; but the

White-Lias beds are not so arenaceous as his statement that they are 'somewhat sandy' would lead one to suppose.[1]

Between Harbury and Ufton there are two quarries in the White Lias, and formerly there were extensive workings at Stoneythorpe.[2]

Many fossils from the White Lias have been obtained from Bascote, Print Hill, and the neighbourhoods of Long Itchington and Stockton. Some are now housed in the Museum at Warwick.

There are no sections of the Rhætic beds between Long Itchington and Church Lawford.

At Church Lawford, however, the buried escarpment of the Rhætic is cut through by the Rugby and Coventry Branch of the London and North-Western Railway. At the time that the railway was constructed there must have been displayed a most interesting section, showing the sequence of deposits from the Red Marls of the Keuper to the *Angulatus*-Beds of the Lower Lias. But now nothing more than the White Lias, the very bottom-portion of shaly clays and Drift, can be seen: all the other beds are hidden by grass.

The White Lias is much fissured, the cracks are filled in with calcite, and in places it is very ferruginous. The beds on the whole are singularly barren of fossils, and the top-band is "pebbly" and has a waterworn, bored, and pitted upper surface. A similar bored bed has apparently been observed in

> "the bed of the Church Lawford Brook, on the left-hand side of the road. The surface of the rock pierced by these worms is very peculiar and striking, every square inch being indented with their burrows".[3]

Resting directly upon the White Lias are clayey shales. The greater portion of these shales is replete with the radioles and portions of the tests of *Cidaris*. Owing to the long exposure of the clay-banks remains of specimens of *Cidaris* appear to occur in the bottom-portion of the clays on top of the White Lias; but Mr. E. Cleminshaw tells me that he has collected examples of *Ammonites planorbis* here, and he thinks that about the lowest 3 feet of the shale-deposit belongs to the *Planorbis*-Zone. The *Cidaris*-Shales appear to be comparable with those that were exposed in the cuttings on the new South Wales Direct Line near Chipping Sodbury.[4] There they were separated from what remains of the White Lias by the *Ostrea*- and *Torus*- (or *Johnstoni*)-Beds: the true *Planorbis*-Zone was not represented. Here, on the other hand, the *Ostrea*-Beds do not appear to be represented: the *Planorbis*-Shales apparently rest non-sequentially upon the White Lias.

The *Cidaris*-Shales are succeeded by the *Angulatus*-Beds, whose limestones—usually with those of the overlying *Bucklandi*-Beds—are so extensively worked for burning for lime at the large Portland Cement Works at Newbold-on-Avon,[5] New Bilton (near

[1] *The Jurassic Rocks of Britain—The Lias*, etc., vol. iii, p. 159, 1893.
[2] Q.J.G.S., vol. xl, p. 364, 1884.
[3] T. B. Oldham, Report Rugby Sch. Nat. Hist. Soc., 1879, p. 11.
[4] Q.J.G.S., vol. lviii, pp. 720–1, 1902.
[5] In some of the indurated shales Ostracoda are very abundant, together with specimens of *Pseudomonotis papyria* (Qu.), and indicate precisely the same horizon as at Maisemore, near Gloucester (Proc. Cotteswold Nat. F.C., vol. xv, pp. 256–62).

Rugby), Long Itchington, Harbury, and Upper Goldicot, near Ettington (near Stratford).

Mr. H. B. Woodward is the only author who has recorded any details of the Church-Lawford section.[1] He observed the *Cidaris*-Shales resting upon "greenish-grey marl, 5 to 8 feet" thick, and these in turn upon the red and green marls of the Keuper. He stated that it is noteworthy that the *Pteria-contorta*-Shales "are not represented at this locality", and elsewhere adds[2] "nor in the Rugby well, and they are poorly represented in other parts of Warwickshire".

J. M. Wilson recorded the details of the well-sinking[3] referred to by Mr. Woodward. Mr. Woodward's conclusion that the Black Shales are absent from beneath Rugby depends upon the identification of 10 feet of 'hard light stone', which rests upon 'red clay', that is, Keuper Marls. Mr. Woodward regards this 'hard light stone' as White Lias.[4] I am inclined to follow J. M. Wilson, who considered the 12-foot bed of limestone reached at a depth of from 390 to 402 feet from the surface that subdivision, and Wilson's "dark and brown clays [58 feet]" and "black clay [20 feet]" the equivalents of the Cotham and Westbury Beds of the Rhætic. The 'hard light stone', according to this view, would be Tea-green Marl (Keuper).

In times past the White Lias was frequently exposed in the neighbourhood of Church Lawford, and a number of fossils have been recorded.[5] But now all the small lime-works have been closed, and the only place at which I noticed traces of White Lias was at the locality called 'Bath', near Kings Newnham. Here there are a great number of old kilns, mainly constructed of White Lias that was doubtless obtained from the workings. The pieces of rock built into the kiln walls are, except for what must have been the top-bed, scantily-fossiliferous. This top-bed is very ferruginous, extremely rich in specimens of *Pseudomonotis*, and has a waterworn and bored upper surface. Thence northwards to the county-boundary the solid rocks are hidden by drift.

NOTICES OF MEMOIRS.

I.—A Remarkable Sarsen or Greywether.[6] By A. Irving, D.Sc., B.A.[7]

WITHOUT desiring to add to the existing plethora of literature on these rocks the author thinks that this sarsen is worth special notice. It was discovered last winter in digging a grave in the

[1] *The Jurassic Rocks of Britain—The Lias*, etc., pp. 151, 162.
[2] Horizontal Section (Geol. Surv.), Sheet 140, and Explanation, 1891, p. 10.
[3] Report Rugby Sch. Nat. Hist. Soc., 1868, pp. 41–2 and plate.
[4] *The Jurassic Rocks of Britain—The Lias*, etc., p. 165.
[5] E. Cleminshaw, Report Rugby Sch. Nat. Hist. Soc., 1867, p. 32; ibid., 1868, p. 43; T. B. Oldham & G. Jones, ibid., 1877, p. 48; T. B. Oldham, ibid., pp. 49–54.
[6] A popular account of this block was given by the author in the *Herts and Essex Observer*, January 7, 1911.
[7] Read before Section C (Geology), British Association, Portsmouth, September, 1911.

Bishop's Stortford Town Cemetery, about 7 feet from the surface in the principal Boulder-clay of the district, the equivalent of the Chalky Boulder-clay of the Eastern Counties.

The block is fairly angular, approximately a cube. On one side the fracture of the bed is fairly fresh; the opposite side is slightly hollowed, as if by the long-continued current action of a shingly stream. For the greater part of its thickness it is a true sarsen; towards the base a few flint pebbles are scattered through it; the upper surface passes into a true 'puddingstone' (an agglutinated mass of flint pebbles), the matrix of which is lithologically the same as, and continuous with, the material of the sarsen. About the middle of the upper side the agglutinated mass of pebbles fills a small gully in the quondam sand of the sarsen. A subordinate alternation of the true sarsen structure with the pebble-bed structure is seen in the largest examples of puddingstone perhaps in the county.[1] A striking lithological feature of this specimen is the distribution in it of numerous small angular bleached fragments of flint. Its dimensions are 30 × 20 × 18 inches, and its weight not less than half a ton. No trace of glacial striations has been detected on it.

The author refers to his former work on the genesis and distribution of sarsens.[2] While recognizing their common occurrence in the Lower Eocenes, and even in the sands of the Neocomian, he regards those of the interior of the London Basin as the wreckage of a younger formation (late Eocene or Oligocene), possibly the stratigraphical freshwater equivalents of the *Stettiner Sandstein* of North Germany[3] and the *Grès de Fontainebleau*[4] of the Paris Basin. Agglutinated portions of the Bagshot Pebble Beds in situ, with similar siliceous cementation, are known to occur;[5] there is good evidence of the quondam extension of the younger beds of the Bagshot Series (including the pebble beds) over Herts and Essex; and the author points to this recently unearthed rock-mass as tending to clinch the view advocated by him for years past—that the sarsens and the Herts 'puddingstone' are remnants of one and the same *younger* Eocene (or Oligocene) formation.[6] He considers the latest treatment of the subject by the late Professor T. Rupert Jones, F.R.S., and the more recent treatment of it by H. B. Woodward, F.R.S.,[7] inadequate.

[1] Seen in the grounds of G. E. Pritchett, Esq., F.S.A., Oak Hall, Bishop's Stortford.

[2] P.G.A., viii, No. 3, 1883, where critical reference is made to the views of the late Professor John Phillips, F.R.S., of Oxford.

[3] H. Credner, *Géologie* (Leipzig), 10th ed., pp. 692 ff.

[4] S. Meunier, *Les causes actuelles en Géologie*, p. 289; Credner, op. cit., p. 683.

[5] A. Irving, P.G.A., xv, pp. 196, 236, February, 1898.

[6] A. Irving, "High Level Plateau Gravels, etc.": GEOL. MAG., No. 484, October, 1904.

[7] *The Geology of the London District* (Mem. Geol. Surv., 1909).

REVIEWS.

I.—Scottish Geological Survey Memoirs.

1. The Geology of the Glasgow District. By C. T. Clough, L. W. Hinxman, the late J. S. Grant Wilson, C. B. Crampton, W. B. Wright, E. B. Bailey, E. M. Anderson, and R. G. Carruthers. With contributions from G. W. Grabham, J. S. Flett, and G. W. Lee. 8vo; pp. x, 270, with 33 text-illustrations and 1 contour map. 1911. Price 4*s.* 6*d.*

IF many hands make light work the production of this memoir ought to have been an easy task, especially as the above list does not contain the names of all who were officially engaged in the Geological Survey of the area, the original maps (published 1870–8) having been the work of E. Hull, J. Geikie, B. N. Peach, and R. L. Jack. Moreover, there are contributions in the memoir from other members of the Survey: notes on fire-clays by J. Allen Howe, with analyses by E. G. Radley, and a bibliography by D. Tait. The colour-printed map which accompanies the present memoir includes portions of the Sheets 22, 23, 30, and 31, the geology has been thoroughly revised, and the map (price 2*s.*) has been specially prepared for economic and educational purposes, with Glasgow as a centre. The map itself contains a wonderful amount of information, the details of the basaltic rocks being enough to appal an ordinary student; it is, however, very clearly printed, and the Glacial Drift is shown by different patterns of stippling.

The Old Red Sandstone, the oldest formation in the district, is separated into Upper and Lower divisions, which are unconformable and palæontologically distinct. Nevertheless, the evidence of these features has to be sought in other areas, as no fossils have been found locally, and "there is no direct evidence of the unconformity elsewhere so strikingly developed". The view is favoured that the Old Red Sandstone was formed under continental conditions with desert, lacustrine, and river action; while the cornstones of the Upper division are likened by Mr. H. B. Maufe to the 'kankar', which in India and Central Africa has been formed in areas subject to wet and dry seasons.

To the Carboniferous rocks Glasgow owes much of its wealth and importance, and full particulars are given of the Calciferous Sandstone Series, with its many basaltic lava-flows, of the Carboniferous Limestone Series, the Millstone Grit, the Productive Coal-measures, and the Upper Barren Red Measures. Practical information is given concerning the coals, the correlation of seams, the cement-stones, limestones, ironstones, and fire-clays. The conditions of sedimentation are dealt with both in the stratigraphical and palæontological chapters, and in the latter due acknowledgment is made of the classic work of the Rev. David Ure, *The History of Rutherglen and East Kilbride*, published in 1793. In that work many of the familiar fossils, the names of which appear in the lists from the Carboniferous rocks of Britain and the Continent, were described for the first time. There is much of interest in the chapter contributed by Dr. Lee, whose initials

(G. W. L.) appended to his work happen to coincide with those of another member of the Survey, Mr. Lamplugh. In regard to the marine beds Dr. Lee points out that "Similarity of conditions induced a similarity in the nature of the fauna". Thus certain abundantly represented species disappear more or less suddenly, and then reappear at a higher horizon, or in other cases vanish altogether so far as this region is concerned. Changes in the position of the shore-line, or of the rivers and marine currents, are justly considered to have influenced the distribution of many organisms.

The Igneous rocks include the Carboniferous lava-flows of the Campsie Fells and Kilpatrick Hills on the north, and those of the Cathkin Hills in the south. Descriptions are also given of various volcanic vents, dykes, sills, etc.

The general structure of the ground is described in a separate chapter, and illustrated by a longitudinal section on the colour-printed map, and by other sections in the text; the faults also are described, some having throws of about 300 fathoms.

No attempt is made to give a complete account of the glaciation of the area, or to describe in detail the Pleistocene deposits of the Clyde Valley. The pre-Glacial topography of Glasgow and its immediate neighbourhood is shown on a colour-printed map, depicting the land as it stood at least 300 feet above present level. A depression of the area almost to present level then took place, accompanied by silting up of valleys. Afterwards came the advance of the great ice-sheet, from the north and north-west, the deposition of boulder-clay, and the formation of drumlins, etc. The retreat of the ice was followed (1) by the accumulation of the 100 foot beach-deposits with sub-Arctic fauna, (2) by elevation and the formation of the 50 foot beach, and (3) after other changes, of the 25 foot beach. The present physical features and river-systems are described, and reference is made to the influence of geography and geology on the rise and progress of Glasgow.

A chapter on Economic Geology, illustrated with figures of micro-slides of rocks, gives abundant practical information relating to the products of the Carboniferous rocks as before mentioned, with particulars of Lime and Cement, Sands, Brick-clays, Paving-setts, Road-metal, and Building-stones. The Building-stones are mostly Carboniferous sandstone, but it is noted that Portland Stone has been introduced. The subject of Water Supply is also dealt with, Glasgow receiving water from Loch Katrine, 34 miles distant. Two wells over 1,000 feet deep are mentioned, one of them yielding highly saline water.

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2. The Geology of Colonsay and Oronsay, with part of the Ross of Mull. By E. H. Cunningham Craig, W. B. Wright, and E. B. Bailey; with notes by C. T. Clough and J. S. Flett. 8vo; pp. viii, 109, with 21 text-illustrations and 6 plates. 1911. Price 2*s.* 6*d.*

IT is perhaps unfortunate that the colour-printed map Sheet 35 (price 2*s.* 6*d.*), of which this memoir is descriptive, contains no part of Oronsay and not quite the whole of Colonsay. The missing

portions might have been inserted, in the space of about nine square inches, on the broad margin of the map. An uncoloured geological map, on the scale of 2 miles to 1 inch, of the two islands is, however, given in the frontispiece to the memoir. The geology of the islands, described in Part I, is by Messrs. Wright and Bailey. The Lewisian Gneiss is exposed over a few acres in the north of Colonsay, but it is mainly covered by Blown Sand. The two islands of Colonsay and Oronsay are formed chiefly of Torridonian, a single conformable series, probably 5,000 feet thick, composed of grits or arkoses, epidotic beds, sandstones, flags, mudstones, phyllites, and limestones. These are shown on the map in eight divisions, which embrace in all seventeen minor lithological divisions. The mapping clearly shows the general structure of the strata, which dip to the east and north-east, but it is remarked that there is much complexity of minor folding in the series. In a footnote the authors state: "Without in the least suggesting a correlation, it is interesting to note that in all save metamorphism the Colonsay flags resemble the banded semi-siliceous granulites known as 'Moines' in the Central Highlands." Considerable attention has been given to the cleavages in the Torridonian and associated rocks.

The igneous rocks include the syenite of Kiloran Bay, the diorite of Scalasaig, and the kentallenite of Balnahard; also minor intrusions of lamprophyre, basalt, and felsite, and certain north-west dykes of dolerite and monchiquite.

Evidences of severe glaciation are seen in the small area of Lewisian gneiss and elsewhere—glaciation that was effected by ice from the mainland from east to west. Support is given to the view of the glacial origin of the sea-floor basin between Oronsay and Colonsay, as advocated many years ago by Professor J. Geikie. The few sections of Boulder-clay show it in an oxidized form as a red and often stiff and tenacious clay, which forms wet rushy ground. There are also many scattered boulders.

Post-Glacial raised beaches occur at the 100, 50, and 25 foot levels, the last named having been formed during early Neolithic times, in a period of marked cave formation. A brief account is given of the submerged Forest of Loch Fada, Colonsay, where stumps and large trunks of trees (including Goat Willow) occur. It is observed that no trees of the size exist in the valley at the present day, with the exception of the artificially protected plantations and woods at Kiloran. The submergence seems to have been caused by a later transgression of the lake due to the raising of its outlet by the growth of peat.

The islands nowhere attain an elevation of 500 feet, and are probably a remnant of an old plain, 400 to 500 feet above sea-level, to the age of which, however, there is no clue. There is evidence of pre-Glacial marine erosion in a plain, with ancient sea-cliffs, at an elevation of 135 feet. Among other interesting observations are those made on the development of the present topography. There is a good deal of fertile land, largely due to the distribution of shell-sand by winds. The debris from crags of phyllite affords good soil for pasture-land, and the raised beaches a lighter soil suitable for corn. The

scenery has many points of great beauty, and the islands may be visited in summer; but sometimes they are "in the winter season for weeks together out of communication with the main land except by telegraph".

Part II, on part of the Ross of Mull and adjacent islands, is by Mr. Craig. The area of Mull, mostly under 400 feet in elevation, is a rough and craggy district of red granite with fine sandy bays. The granite is quarried in the district to the north of that shown on the map. It is regarded as of later Palæozoic age, and it sends veins into the Moine Series. J. G. Goodchild's view that "granite veins have evidently eaten their way into the surrounding rock" is mentioned, but not discussed. The Moine Series consists of metamorphic schists, with intrusive sills of hornblende schist containing abundant garnets. The north-west dykes of dolerite, camptonite, and monchiquite may possibly all be of Tertiary age, like the sheets of columnar dolerite and the two tiny intrusions of granophyre.

Glacial drift mostly occupies small hollows; raised beaches occur as on Colonsay, and there are tracts of shelly blown sand and peat mosses.

II.—Russian Fossil Elephants.

Les Éléphants fossiles de la Russie. By Marie Pavlow. Nouveaux Mémoires de la Société impériale des Naturalistes de Moscou, vol. xvii, pt. ii, pp. 57, 3 plates, 1910.

THIS important memoir by Madame Pavlow describes in detail a quantity of proboscidean remains for the most part from the early Pleistocene deposits of Tiraspol in Southern Russia, but also from other localities. Most of the specimens were originally referred to the species *Elephas trogontherii*, Pohlig, which is, in fact, a primitive form of the Mammoth, but on further examination of the remains the author has come to the conclusion that many of them represent a still more primitive type in which the plates of the molars are wider and fewer in number; to this form she has given the name *Elephas wuesti*.

In discussing the nomenclature of the cheek-teeth in elephants the author objects to the use of the term 'milk-molars' for the three anterior molars, on the ground that they are not replaced by pre-molars. Since, however, from the history of the dentition in the group, it is certain that the replacing pre-molars have only lately been suppressed, some even occurring in one species of *Elephas* proper (*E. planifrons*), it is certain that these anterior molars are homologous with the milk-molars of ordinary mammals, and nothing is gained by concealing this fact by giving them other names.

In addition to *E. wuesti*, remains of several other species of *Elephas*, e.g. *E. antiquus* and *E. armeniacus*, are described from the same deposits: this assemblage does not seem very probable, and perhaps sufficient allowance has not been made for the considerable range of individual variation that may occur in elephant molars.

In the last part of the paper Madame Pavlow discusses the relationship of the later elephants to one another. She is of opinion that the Mammoth and the Indian elephant are not so nearly related to one

another as is commonly believed, and that, in fact, they had a different ancestry, the Mammoth being descended from a broad-plated type of *E. meridionalis* through *E. wuesti* and *trogontherii*, while the Indian species are descended from a thin-plated form of *E. meridionalis* through *E. antiquus* and *E. namadicus*. It seems, however, more probable that both the Mammoth and the Indian elephant are descended from some such species as *E. armeniacus*, which is very near to *E. wuesti*. The African elephant is regarded as having sprung from *E. namadicus* through *E. priscus*.

Although it is not always possible to agree with the author's conclusions, her detailed and careful descriptions of these Russian elephants make a very important contribution to our knowledge of the group.

C. W. Andrews.

III.—Über die innere Organisation und Stammesgeschichte einiger irregulärer Seeigel der obern Kreide. (On the Internal Structure and Phylogeny of some Irregular Sea-urchins of the Upper Chalk.) Von Dr. Franz Klinghardt. Jena, 1911.[1]

BY a study of the flint-casts and of the cleaned interiors of the tests of certain Cretaceous sea-urchins, Dr. Franz Klinghardt establishes points of extreme interest with regard to the comparative morphology of various fossil and recent echinoids. The material examined was collected from the Senonian of the South of England, the Maestrichtian of Maestricht, and the Danian of Malmö, Sweden; and recent specimens were studied at the biological stations at Plymouth and Lowestoft. Frequent reference is made to the recent *Spatangus purpureus*, since it admits of close comparison with the common *Micraster* of the English Senonian.

Particular attention is paid to the impressions on casts of the intestinal tract, and of the supports of the mouth, the gonads, and the water-vascular system. Dr. Klinghardt points out that in many casts the exact course of the alimentary canal and its mesenteries can be traced, and he is thus able to institute a comparison amongst the following forms: *Ananchytes ovatus*, *Hemipneustes radiatus*, *Micraster cor-anguinum*, and *Echinoconus albogalerus*. The mouth-supporting apparatus has been considered in detail, and the significance of its fuller development in *Spatangus purpureus* than in *Micraster cor-anguinum* has been pointed out. In the discussion of the impressions left by the gonads, the statement of Hoffman that they projected into the body-cavity is shown to be incorrect. In some of Dr. Klinghardt's fossil casts the position and form of the ampullæ, which in recent urchins may be found occupied partly by water and partly by sand and mud, were found to be still clearly indicated, their various degrees of contraction being recognizable. The author's minute examination of the traces of the water-vascular system establishes most interesting resemblances and differences between fossil and recent echini. In one specimen, for instance, the ampullæ

[1] Inaugural-Dissertation zur Erlangung der Doktorwürde der math.-nat. Fakultät der Grossherzogl. Bad. Albert-Ludwigs-Universität zu Freiburg im Breisgau vorgelegt von Franz Klinghardt. Jena, 1911. (Privately printed.)

are indicated by an apparently chalky deposit, their condition being thus analogous to the sand-filled ampullæ of some recent Spatangids.

Among the minor points discussed are the traces of the cœlomic epithelium in *Echinoconus*, the rudimentary perignathic girdle in *Ananchytes*, and the notable differences, chiefly in the disposition of the pores, between the inside and the outside of the ambulacra of *Echinoconus*. Furthermore, the growth-bands in *Spatangus purpureus* and *Micraster cor-anguinum* are shown to be similar. Dr. Klinghardt's examination of specimens of *Ananchytes* from the Danian of Malmö and the Senonian of England has enabled him to determine that changes have taken place in their internal organization at different horizons as well as in the shape-variations familiar to chalk-workers. The positions of the gut-line and of the water-vascular system in particular show these changes. Another interesting fact is brought forward, viz., that one finds in specimens from the *Marsupites*-zone a slight swelling of the ambulacral plates in the direction of the inter-ambulacra. As a result of this, the water-vascular system comes to lie in a kind of channel: the fine peristomial structure has in consequence gradually shrunk, and has disappeared altogether in examples from Malmö. The important conclusion derived from a detailed comparison between *Spatangus purpureus* and *Micraster* is that *Spatangus* recapitulates the *Micraster*-stage in its ontogeny.

In addition to the purely palæontological details, Dr. Klinghardt has furnished many observations of great geological interest. At Newhaven he noted a deposit in process of formation that he considers to explain the origin of echinoderm breccias. This was a silt, rich in broken echinoderm tests, that had accumulated in a sheltered creek, but owing to the incursions of rough seas had come to be intercalated with coarse-textured bands containing a different fauna. The enormous preponderance of small urchins in some marine beds is shown to be due to the fact that the larger species of which fragments are found had swallowed them together with sea-sand. The Newhaven and the Petersberg (Maestrichtian) echinoderm breccias are proved to have been formed under precisely similar conditions.

Dr. Klinghardt attributes the preservation in flint of the form of the internal organs of fossil sea-urchins to rapid infilling of their tests, due to *sudden* precipitation of silica. In support of this opinion he instances the uniformity of the thickness and sharp definition of the tabular flint bands to be found at certain horizons in the English Chalk. The paper concludes with observations on the œcology of living echinoderms; and reasons are assigned for regarding the variations in the facies of *Ananchytes* and *Micraster* as attributable to differences in nature of habitats.

C. P. Chatwin.

IV.—Cambrian Geology and Palæontology. No. 6: *Olenellus* and other Genera of the Mesonacidæ. Smithsonian Miscellaneous Collections, vol. liii, 1910.

SINCE the publication of the memoir on the *Olenellus* fauna in 1891, Dr. C. D. Walcott has made a large collection of these primitive forms from the Lower Cambrian rocks of the United States,

Canada, and Newfoundland, and has also further examined those derived from rocks of the same age in Britain and Scandinavia. In some of the American rocks very diminutive specimens, representing the early stages of growth of these Trilobites, have been preserved, and from them the author has endeavoured to trace out their lines of development. These fresh discoveries have also provided materials for a thorough revision of the classification of the group, which is worked out in considerable detail. The author states that with the exception of forms referred to *Nevadia* and *Callavia*, in which a small anterior glabellar lobe is present, the variations in the characters of the cephalon throughout the group are only of specific value; and as the pygidium also is essentially similar, the basis for generic separation mainly depends on modifications of the thorax. Five new genera, *Nevadia*, *Pædumias*, *Peachella*, and *Wanneria*, are introduced, and many new species are described and figured on the twenty-two plates. The use of the family term Mesonacidæ in preference to Olenellidæ is justified on the ground that the former has the priority, and that the genus *Mesonacis* is more typical of the family than *Olenellus*.

V.—A Guide to the Fossil Invertebrate Animals in the Department of Geology and Palæontology in the British Museum (Natural History). Second Edition. 8vo; pp. x, 184, with 7 plates. Printed by order of the Trustees. London, 1911. Price 1*s*.

THE first edition of this admirable guide was published in 1907. In the present one may be noticed the omission of a separate account of the Koenig and Gilbertson Collections (p. 9), owing to the specimens having been dispersed among the systematic series. The addition of the Archæocyathinæ (p. 42). A revised account of the Cirripedia (p. 94). Several alterations due to the rearrangement of the Brachiopoda (p. 114). An Appendix (p. 117) noting recent additions to the exhibited series of Mollusca. Fig. 41 is an original figure of the under-surface of *Eurypterus Fischeri*. Fig. 49 is from a new drawing of *Protocarcinus longipes*. Fig. 65*a* represents a Senonian species of *Membranipora*. In making some of these alterations the author, Dr. F. A. Bather, acknowledges the help of Dr. W. T. Calman, Messrs. R. B. Newton, W. D. Lang, and T. H. Withers. The figures throughout the Guide are admirable.

VI.—Grundzüge der Palæontologie.—The preparation of a new edition, the third, of this well-known textbook of Palæontology of the late Professor K. A. v. Zittel, has been carried out by Professor Dr. F. Broili, of Munich, whose friendly help in correcting the proofs of the two earlier editions was gratefully acknowledged by the author of the work. The first part of the present edition, comprising the Invertebrata, is a volume of 607 pages, with 1,414 text-figures and a separate index. About seventy of the figures are new, and to a large number of the older clichés further explanatory letterings have been added. Dr. Broili has endeavoured to incorporate in the volume all the recent discoveries in Invertebrate Palæontology; references are given to the

new literature on the subject which has appeared since 1903, the date of the second edition, and special notice is devoted to the vertical geological range of particular forms.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

I.—*November* 22, 1911.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read :—

1. "Petrological Notes on Guernsey, Herm, Sark, and Alderney." By Professor T. G. Bonney, Sc.D., LL.D., F.R.S., F.G.S., and the Rev. Edwin Hill, M.A., F.G.S.

The authors returned to these islands, after an interval of nineteen years, in order to give further study to the relations of the igneous masses and especially of certain dyke-rocks. As they had themselves suspected in 1891, and as Mr. J. Parkinson had announced in 1907, the old distinction between diorite and syenite could not be maintained; but there existed, especially in Guernsey and Alderney, a dioritic magma which underwent differentiation. The results of this are described, the most basic being found at Fort Albert (Alderney) and Bon Repos Bay (Guernsey), and the most acid, which are really tonalites, more especially in the north-west of the latter island. These and a felspathic variety sometimes intrude, sometimes pass into the others, so they also must have been at high temperature. The so-called 'granites' at the two ends of Sark are hornblendic, the southern one being really a tonalite; so are those of Alderney, Herm, Jethou, and Guernsey, and it is suggested that these granites may be yet more acid terms in a differentiation series.

Of the numerous dykes the most acid are either aplitic micro-granites or quartz-felsites, the latter being the rarer and probably later in date. Some of the former at Castle Cornet exhibit an interesting structure. Here diorite cuts gneiss, and has partly melted down a little of it. Microgranite has also cut and melted some of the diorite, the result being a streaked red and green rock. Diabase dykes are common, and mica-traps have been found in all the islands except Herm. The former almost invariably cut the microgranitic dykes, but are cut by the quartz-felsites.

At Pleinmont, in the south-west of Guernsey, a mass resembling a greenstone proves, as mentioned by the late Père Noury, to be sedimentary. This has been examined and is considered to be, like the 'argillites' of Jersey, Brioverian in age. It is cut by dykes of quartz-felsite and by one of diabase (older than these).

The time-relations of the several rocks are discussed. The gneiss of Guernsey, a pressure-modified granite, is the oldest, and had acquired its structure before the intrusion of the diorites. They were followed by the hornblendic granites, and these by the aplitic microgranites. All were pre-Cambrian, and perhaps even the last was older than the Brioverian. The date of the diabase dykes is more uncertain. They are apparently earlier than the quartz-felsite

dykes, which may possibly be of the same age as the acid lavas below the conglomerate of Eastern Jersey, now regarded as basal Cambrian; but in Alderney two diabase dykes cut the *grès feldspathique*. There is, however, reason to think that these dykes are of more than one age. The mica-traps are probably late Palæozoic.

2. "The Evolution of *Inoceramus* in the Cretaceous Period." By Henry Woods, M.A., F.G.S., Lecturer in Palæozoology in the University of Cambridge.

The species of *Inoceramus* found in the Gault, the Upper Greensand, and the Chalk are considered to have descended from two stocks which occur in the Lower Greensand, one being *I. salomoni*, d'Orb., the other of the type of *I. neocomiensis*, d'Orb.

I. *I. concentricus*, Park. (Lower and Upper Gault), is of the same type as *I. salomoni* (Folkestone Beds and *Mammillatum* Bed), from which it has been derived by the reduction in the length of the hinge-line and in the height of the hinge-area, accompanied by a greater obliquity of the axis of growth.

I. sulcatus, Park. (Upper Gault), closely resembles *I. concentricus*, except that it possesses strong radial ribs. Between these two species every gradation is seen in the form known as *I. concentricus*, var. *subsulcatus*, Wiltsh. (Upper Gault), which in its early stage is identical with *I. concentricus*, but at a later stage develops radial folds; the *concentricus* stage may be of long or short duration, and consequently in some cases the folds occur near the margin of the valves only, but in others may reach to near the umbo, while in *I. sulcatus* they reach to the apex of the umbo.

I. tenuis, Mant. (Red Chalk and Chalk Marl), is allied to *I. concentricus*, from which it has been derived by an increase in the length of the hinge and a decrease in the prominence of the left umbo. *I. etheridgei*, Woods (zone of *P. asper* to zone of *H. subglobosus*), is similar to *I. tenuis*, but its left umbo is smaller, the valves less unequal, and the postero-dorsal region is less compressed.

II. *I. anglicus*, Woods (Gault and Upper Greensand), resembles *I. neocomiensis*, but the posterior part of the shell has become more compressed, and the ventral curvature of the ribs has increased. From *I. anglicus* two species appear to have arisen, namely, *I. pictus* and *I. crippsi*.

A. *I. pictus*, Sow. (Chalk Marl to *H. subglobosus* zone), approaches the form of *I. anglicus*, which has more numerous and more regular ribs; and in it the ribs have become still more numerous and more regular, and the anterior area has become more extensively developed.

I. lamarcki, Park. (zone of *Rh. cuvieri* to zone of *M. cor-anguinum*), shows a great amount of variation. An early form has nearly equal valves and only slightly developed concentric folds, and approaches closely *I. pictus*, from which it is believed to have been derived.

I. involutus, Sow. (zones of *M. cor-testudinarium* and *M. cor-anguinum*), is linked by intermediate forms with the variety of *I. lamarcki*, which has a very convex left valve and prominent umbo. In the intermediate forms the left valve loses its folds and develops a large, spirally-coiled umbo; the right valve becomes less convex and gradually loses its anterior area, but retains the strong concentric folds.

I. cordiformis, Sow. (zone of *M. cor-testudinarium* to *Uintacrinus* Band), has been derived from a variety of *I. lamarcki*, with inflated and nearly equal valves, by the development of one or two radial sulci and a relatively longer hinge.

I. costellatus, Woods[1] (Chalk Rock), appears to have come from an early form of *I. lamarcki* by the axis of growth becoming more oblique to the hinge and by the development of a more pointed umbo.

I. subcardissoides, Schlüt., *I. digitatus*, Sow., *I. pinniformis*, Will., and *I. corrugatus*, Woods,[2] are allied one to the other, and appear to have arisen from the less convex forms of *I. lamarcki* by the development of radial folds such as occur occasionally in *I. lamarcki* and allied species.

B. *I. crippsi*, Mant. (Upper Greensand to zone of *H. subglobosus*), agrees in many respects with the form of *I. anglicus*, which has fewer and less regular ribs, but in this species the hinge has become somewhat shorter, the postero-dorsal part of the shell less compressed, the anterior area smaller, and the ribs fewer and more irregular with a less strongly marked posterior curvature.

In *I. crippsi*, var. *reachensis*, Eth. (Chalk Marl to zone of *H. subglobosus*), the shell has become relatively higher and the posterior curvature of the ribs greater: this variety resembles closely the small forms of *I. labiatus* (Schloth.) (zones of *Rh. cuvieri* and *T. lata*); but in later stages the shell in that species grows extensively in a direction oblique to the hinge, and thus acquires a mytiliform shape. In the zone of *Terebratulina lata* the specimens of *I. labiatus* are usually longer and less high than in the zone of *Rh. cuvieri*, and these pass into *I. labiatus*, var. *latus*, Sow. (*H. planus* zone).

I. inconstans, Woods[3] (zone of *H. planus* to zone of *B. mucronata*), undoubtedly belongs to the *labiatus* stock, and the nearly flat forms approach closely *I. labiatus*, var. *latus*, from which they have probably been derived.

I. balticus, Böhm (zone of *Marsupites* to zone of *B. mucronata*), possesses many of the characters of *I. inconstans*, from which it has developed by an increase in the length of the hinge.

I. lingua, Goldf. (zones of *Marsupites* and *A. quadratus*), is similar to the nearly flat forms of *I. inconstans*, but the shell has become higher. *I. lobatus*, Goldf. (zones of *Marsupites* and *A. quadratus*), is near to *I. lingua*, but has developed an angular ridge between the umbo and the postero-ventral extremity. *I. cardissoides*, Goldf. (zone of *A. quadratus*), and *I. tuberculatus*, Woods[4] (zone of *A. quadratus*), are closely related to *I. lobatus*.

I. undulato-plicatus, Röm. (Upper Chalk), resembles the nearly flat forms of *I. inconstans*, from which it appears to have been derived by the development of diverging radial folds.

[1] Q.J.G.S., vol. liii, pl. xxvii, figs. 14–17, 1897.
[2] Type, British Museum, L 22528.
[3] G. A. Mantell, *Foss. S. Downs*, pl. xxvii, fig. 9, and pl. xxviii, fig. 3, 1822; and F. Dixon, *Geology of Sussex*, pl. xxviii, fig. 29, 1850.
[4] Type in Dr. A. W. Rowe's collection, from Sewerby (Yorkshire).

December 6, 1911.—Professor W. W. Watts, Sc.D., LL.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Faulted Inlier of Carboniferous Limestone at Upper Vobster (Somerset)." By Thomas Franklin Sibly, D.Sc., F.G.S.

The three small masses of Carboniferous Limestone at Luckington, Upper Vobster, and Tor Rock, Vobster, respectively, which lie in the overfolded Coal-measures of the southern portion of the East Somerset Coal-field, have been the subject of comment and speculation by many writers since two of them were first noticed by Buckland & Conybeare.

The Upper Vobster inlier is by far the largest of the three. Intermediate in position, it lies rather less than a mile to the north of the main outcrop of the Carboniferous Limestone of the Eastern Mendips. This inlier has been dissected to a remarkable extent by quarrying operations, and its structure is described in detail in the present paper.

The northern and eastern portions of the inlier are concealed by a thin covering of Lias, but its maximum width from north to south is probably little, if at all, greater than 400 yards, while the proved east-and-west extent of the Carboniferous Limestone is about 1,100 yards.

From personal observation, combined with important evidence recorded by previous investigators, the author has arrived at the following general conclusions:—

(1) The inlier is apparently a lenticular mass of Carboniferous Limestone, grits, and shales, superimposed upon the overfolded strata of the Coal-measures by powerful thrust movements.

(2) It comprises (*a*) a Northern Limestone Mass and (*b*) a Southern Limestone Mass, separated by (*c*) a Grit-and-Shale Mass.

(3) The beds of the Grit-and-Shale Mass are in faulted relation to the Carboniferous Limestone on both sides. On the northern side the immediately adjacent beds of limestone represent part of the *Seminula* Zone; on the southern side the adjacent beds belong to the Lower *Dibunophyllum* Zone. On both sides the limestones are locally distorted.

(4) In the Northern Limestone Mass, Vobster Quarry exposes over 500 feet of *Seminula* Beds, overfolded towards the north-west, and dipping south-eastwards at an angle of about 135°.

(5) In the Southern Limestone Mass, where portions of the Lower *Dibunophyllum* Zone and the Upper *Seminula* Zone are exposed, the strata are locally overfolded northwards.

(6) The beds of the Grit-and-Shale Mass comprise quartzites which must certainly be assigned to the Millstone Grit. They also include shales, with intercalated fine-grained sandstones, of considerable thickness. Possibly this mass includes the lowest beds of the Coal-measures, in addition to a portion of the Millstone Grit.

(7) In most of the sections of Carboniferous Limestone, signs of the immense stresses to which the strata have been subjected are very evident. The beds are often distorted, while slickensides and calcite veins are extensively developed on both a large and a small scale.

The occurrence of a Lamellibranch fauna at the top of the *Seminula* Zone is recorded as a feature of special interest.

2. "Geology of a Part of Costa Rica." By James Romanes, B.A., F.G.S.

The paper deals chiefly with that part of Costa Rica which lies to the west of San José as far as the Pacific coast. San José itself is situated in a wide valley sloping gently westwards, and drained by the Rio Grande and its tributaries (defined in the paper as the San José Valley). The northern boundary of this valley is the chain of recent volcanoes which rise gradually from its floor, while on the south the ground rises abruptly to form the Cerro Candelaria.

In this latter range of mountains are exposures of limestone, marl, etc., together with various igneous rocks. The limestone is that which is referred to the Cretaceous by R. T. Hill; but an examination of several exposures has failed to produce any Cretaceous fossils, while the occurrence in places of vast numbers of *Balani* points to a Tertiary age for the beds. As this limestone stretches right across the Atlantic–Pacific watershed between Cartago and San José, it yields clear evidence of an inter-oceanic connexion in this area in Tertiary times.

Of the igneous rocks, the most interesting feature is the presence of many boulders of monzonite, indicating a plutonic mass in these mountains. The surface of the San José Valley is composed of a thick series of andesitic lavas into which the rivers have cut deep gorges, exposing in some cases older river-deposits and buried spurs of the Cerro Candelaria. On the Pacific coast at Barranca and Manzanilla fossiliferous Tertiary beds are described. These are all marine ashes, and in the Manzanilla district appear to rest unconformably on an older limestone formation. From the same area a limburgite is recorded.

The dominant features of the Pacific shore-line are due to drowning, instead of to uplift as is the case on the Atlantic coast; these features have, however, been considerably modified by subsequent alluvial deposits.

The 'boulder-clays' of Costa Rica are shown in many cases to be normal river-deposits, though locally landslides and spheroidal weathering have played an important part. These deposits in the valley of the Rio Reventazon point to several distinct phases of river-action.

II.—Geologists' Association.

December 1, 1911.—Mr. William Hill, F.G.S., President, in the Chair.

Dr. A. Smith Woodward read a paper on a maxilla of *Triconodon ferox* discovered by Mr. John Newton in the Purbeck Beds of Swanage. The fossil was obtained from the 'Cap Stone', about 26 feet above the well-known Middle Purbeck mammal-bed, and just below the 'Feather', in which the only known jaw of *Triconodon major* was found. The fourth premolar and the three molars are perfectly preserved, and the third molar is shown to be reduced in size, with only two cusps.

OBITUARY.

SIR JOSEPH DALTON HOOKER,

O.M., G.C.S.I., M.D., D.C.L., LL.D., F.R.S., F.G.S., ETC.

BORN JUNE 30, 1817. DIED DECEMBER 10, 1911.

AT the advanced age of 94 there has passed away at his home, The Camp, Sunningdale, in Berkshire, the most eminent of British botanists. By extended observation in all quarters of the globe and prolonged research he threw light on many difficult problems in natural history, aiding and supporting Darwin and Lyell on the origin of species, and on the causes which have influenced the geographical distribution of plants and the production of insular floras. He was the second son of Sir William Jackson Hooker, who, born at Norwich, married the eldest daughter of Dawson Turner, F.R.S., botanist, antiquary, and also banker, of Great Yarmouth. Other daughters of Turner were married respectively to Sir Francis Palgrave, the Rev. John Gunn (Rector of Irstead, Norfolk), Bishop Jacobson of Chester, and T. Brightwen of Yarmouth. Having independent means Sir William Hooker settled at first at Halesworth in Suffolk, where his son Joseph was born. Afterwards he removed to Glasgow on being appointed Professor of Botany in the University, and subsequently he became Director of the Royal Gardens at Kew.

J. D. Hooker was educated at the High School and University at Glasgow, where he qualified as M.D. in 1839. He inherited his father's tastes for Natural History, and Botany in particular, and was fortunate in being appointed assistant-surgeon and naturalist on board H.M.S. *Erebus* in the great expedition conducted by Sir James Clark Ross to the Antarctic regions during the years 1839–43. The botanical observations made in the course of that voyage were published in six volumes (1844–60), and dealt with the plants of New Zealand and Tasmania, as well as those of Antarctic lands. The philosophic conclusions bearing on the causes of the geographical distribution of the plants were published in 1859, in a now classic memoir *On the Flora of Australia, its origin, affinities, and distribution, being an Introductory Essay to the Flora of Tasmania.*

In 1846 Hooker was appointed Botanist to the Geological Survey of Great Britain, under Sir Henry De la Beche. His attention was now directed to the plants of past ages, and in particular to those of the Coal-measures; and he published an essay *On the Vegetation of the Carboniferous Period, as compared with that of the present day*, and two more special papers on the structure of *Stigmaria* and of some Lepidostrobi (Mem. Geol. Surv., vol. ii, pt. ii, 1848).

In 1847 Hooker resigned his appointment on the Geological Survey for the purpose of studying the botany of India, spending the years 1847–51 mostly in the higher mountain regions of that country, and publishing the general results in his famous *Himalayan Journals* (two vols., 1854). Interesting observations were therein included on the delta of the Ganges, and on the parallel terraces in the Himalayas, the formation of which was attributed to the barring of glacier lakes by ice and moraines.

In 1855 Hooker was appointed Assistant Director of Kew Gardens, becoming Director on the death of his father in 1865. Meanwhile he made an expedition to Syria and Palestine in 1860, and apart from his special botanical work made observations on the moraines of extinct glaciers on which some of the ancient cedars of Lebanon grow. In later years he explored parts of Morocco and the Great Atlas in company with John Ball, F.R.S., and George Maw (1871), and visited the Rocky Mountains and California in 1877. In 1885 he resigned his Directorship of Kew Gardens. Hooker was elected a Fellow of the Geological Society in 1846, and served as a member of Council during the years 1852–6 and 1860–2. To that Society he contributed several papers on fossil plants. He became F.R.S. in 1847, and was President of the Royal Society and ex officio a Trustee of the British Museum from 1873 to 1878. In recognition of his distinguished services he received a Royal Medal in 1854, the Copley Medal in 1887, and the Darwin Medal in 1892. He was President of the British Association at the Norwich meeting in 1868. Hooker married (1) the daughter of the Rev. J. S. Henslow, and (2) the daughter of the Rev. W. S. Symonds (Rector of Pendock) and widow of Sir W. Jardine (7th Baronet).

After his retirement from Kew he continued to labour diligently at work connected with his favourite studies. He gave much time to the great *Index Kewensis*, which was prepared under his direction by Dr. B. Daydon Jackson; and he edited, with life of the author (1906), the *Journal of Sir Joseph Banks*, which was kept during Captain Cook's first voyage.

Sir Joseph Hooker was buried in the old churchyard at Kew on December 15. H. B. W.

ROBERT DAVIES ROBERTS, M.A., D.Sc., J.P., F.G.S.

BORN 1851. DIED NOVEMBER 14, 1911.

WE regret to record the death of Dr. R. D. Roberts, who was Registrar of the Board for the Extension of University Teaching in the University of London. He was born at Aberystwith, educated at University College, London, and Clare College, Cambridge, where he took a high position in Natural Sciences, geology at the time claiming his chief attention. He was University Lecturer in Geology in 1884, and in 1893 published *An Introduction to Modern Geology*. During later years his time was given to more general educational work and administration. He was High Sheriff of Cardiganshire in 1902–3.

MISCELLANEOUS.

FLINT IMPLEMENTS.—The *Morning Post* of December 26, 1911, devotes a column to "Flint Implements", "The Flint Collector", "Flints which are not genuine", and "The means by which to distinguish genuine implements from false ones". We fear so long as a clever and dishonest 'flint-knapper' lives and makes *good forgeries* there will always be found simple folks to buy them.